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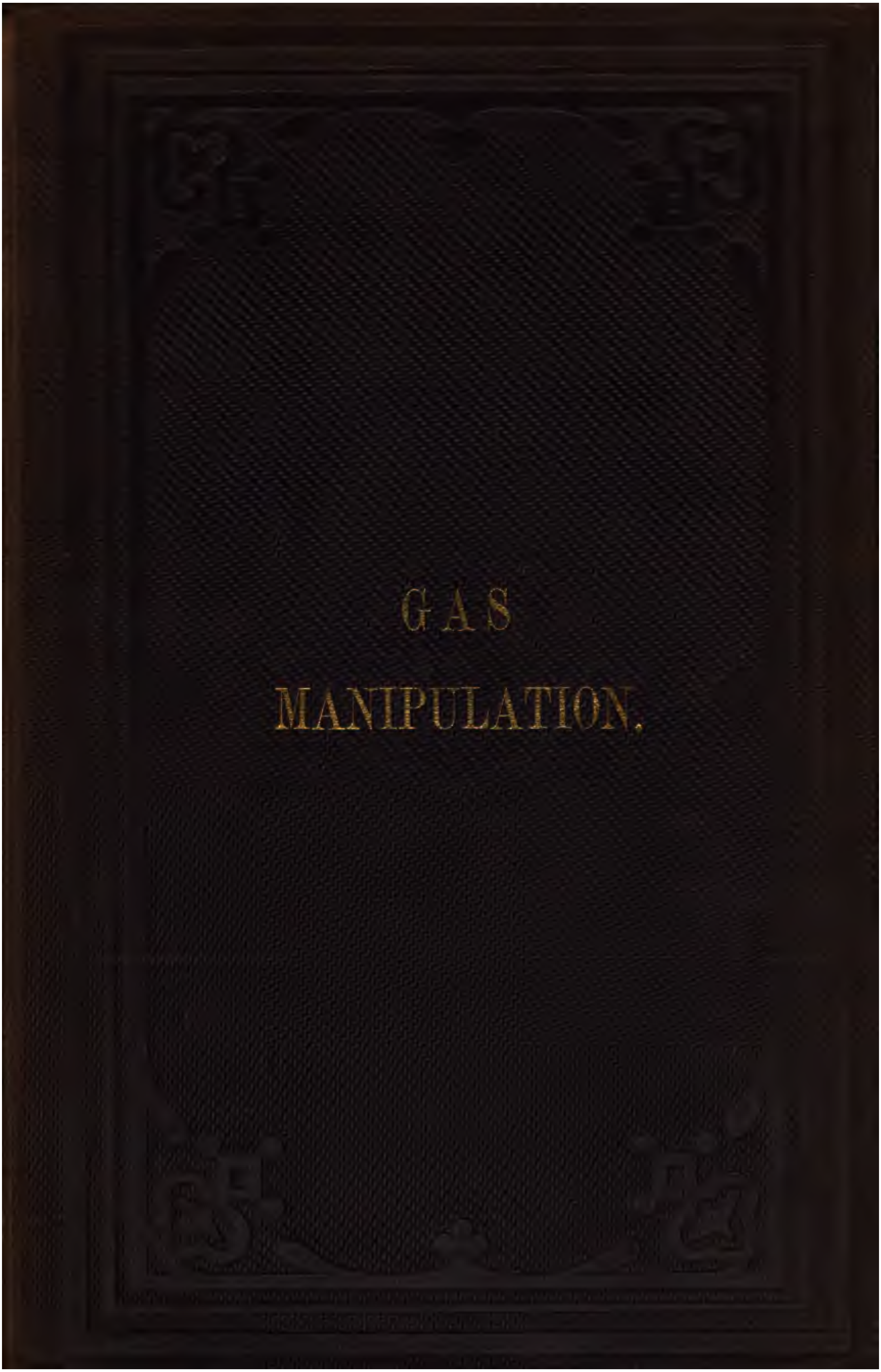

GAS
MANIPULATION.

GAS MANIPULATION,

WITH A
DESCRIPTION OF THE VARIOUS
INSTRUMENTS AND APPARATUS
EMPLOYED IN THE
ANALYSIS
OF
COAL AND COAL GAS.

BY
HENRY BANISTER,
CHARTERED GAS COMPANY,
WESTMINSTER.

LONDON:
19 & 20, MARSHAM STREET, WESTMINSTER.
1863.

[ENTERED AT STATIONERS' HALL.]

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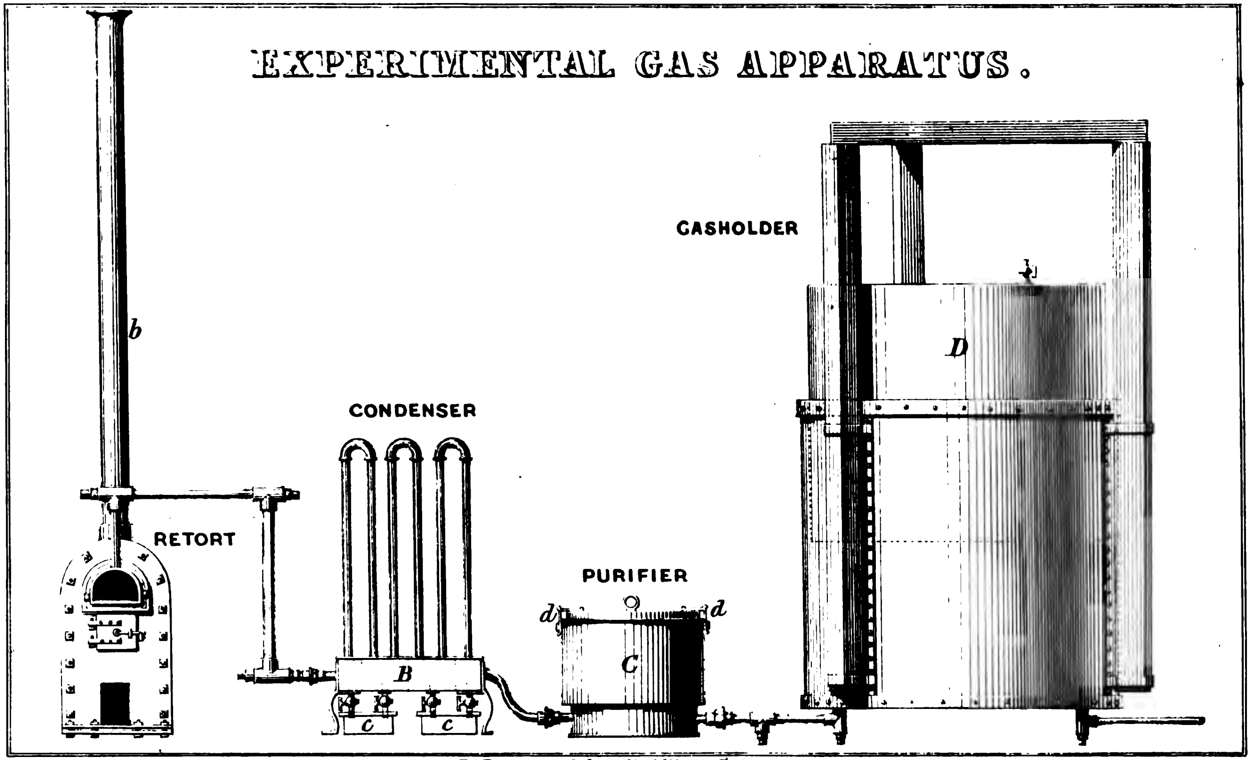
193. e. 5.

BIBLIOTHECA BODLEIANA

W. BLANCHARD & SONS PRINTERS, 62, MILLBANK STREET, WESTMINSTER, S.W.

EXPERIMENTAL GAS APPARATUS.



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INTRODUCTION.

In every large gasworks it now seems to be admitted that the apparatus is not complete without a small experimental retort, and apparatus, for the purpose of analysing any sample of coal, the value of which, as a gas-producing agent, the manager may wish to know. In order, therefore, to assist those who have not given this important subject the attention it deserves, I now most respectfully submit to the profession at large the following description and method of proceeding with experimental apparatus, and other instruments for the analysis of coal, so as to enable any engineer to determine practically the value of any kind of coal submitted to him, without being dependent upon the analysis of the coal-owner or the chemist whom he may have employed; and in doing so I am far from pretending to say that the methods here given will satisfy all the requirements of analytical chemistry, but that they are intended only to meet the wants of practical gas makers, and enable them to determine for themselves, with the accuracy of actual experiment, the quantity of gas and coke produced from a ton of coals, the approximate amount of sulphur and ammonia, the hydro-carbon vapours condensable by bromine, the quantity of carbonic acid and carbonic oxide, the carburetted hydrogen contained in a given volume of gas, and lastly, to determine the illuminating power of the gas, which is, after all, the most important commercial test to which the gas can be submitted.

Instead of describing each individual instrument separately and distinctly, I have thought it better to go through the general analysis of a coal, and to describe the construction and uses of each part of the apparatus, in its proper place, in the several steps of the process. I am quite aware that this course leaves me open to the charge of wandering from the subject more immediately before us; but it has advantages, which, to my mind, are strongly in its favour, and which have induced me to adopt it.

There are many sources from which illuminating gas may be obtained, but the principal and indeed only substances in general demand in this country at the present time are bituminous and cannel coal. Peat and bituminous shale are sometimes used; but the method of analysis will in all cases be nearly the same as that to which our attention is more particularly to be directed.

The following is the order in which I propose to conduct the analysis of a coal, viz.:—

To ascertain its specific gravity.

The quantity of gas it is capable of producing per ton reduced to the standard temperature and pressure.

The per centage { of hydro-carbon vapours condensable by bromine.

" of carbonic oxide.

" { of sulphuretted hydrogen present in the foul gas.

" of carbonic acid ditto.

The specific gravity of the vapours condensed by bromine.

" " purified gas.

The weight, in pounds, of the gas produced from a ton of coal.

The quantity of ammonia or sulphur which may be present in the purified gas.

The illuminating power.

The quantity and value of ammoniacal liquor and tar.

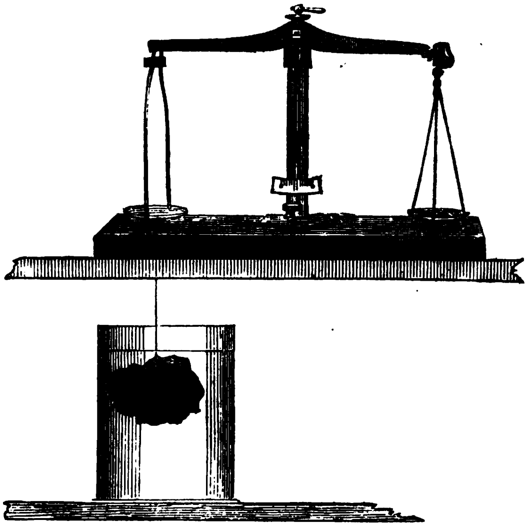
The quantity and quality of the coke.

Too much care cannot be taken in selecting a fair sample of the coal to be tried: it should be clean and dry, for nothing is so much calculated to mislead even an experienced analyst as the presence of moisture in the coal; and, in making a table for himself, which every gas engineer should do, of the constituents of the various kinds of gas coal, he would be misleading himself if he did not take care that every sample of coal analysed was in the same comparatively dry state,—that is, the coals should all be commercially dry. The importance of this condition will be seen when it is stated that nearly all coals contain a certain percentage of iron pyrites, or bisulphuret of iron, and if a charge of damp coals be put into a retort as soon as the exterior portion of the charge is carbonized, the vapour from the water mechanically contained in the interior begins to rise, and is immediately decomposed by contact with the heated surface of the retort and coals. This decomposed watery vapour now comes in contact with the proto-sulphuret of iron given off from the highly heated surface of the charge, the bisulphuret being converted into a proto-sulphuret of iron, and a double decomposition takes place, the result being the production of oxide of iron and sulphuretted hydrogen—a very great evil, which cannot be too carefully guarded against, as the expenses of purifying the gas may by this means be immensely increased.

SPECIFIC GRAVITY OF COAL.

Specific gravity of Coal.

Having chosen a fair sample of the coal, the first thing to be done is to determine its specific gravity. Take a conveniently shaped piece of coal, and having carefully adjusted the balance, suspend the coal by a horse-hair, or a single strand of silk, to the under side of the pan: its weight being ascertained, which I will suppose to be 500 grains, take a vessel of distilled water, and add as many grains to the pan from which the piece of coal is suspended as will just balance it when immersed in the water; suppose it takes 410 grains, then the original weight, 500 grains, divided by this weight, 410 grains, gives the specific gravity of the coal, which in this case would be 1·219.



Description of experimental apparatus.

The next operation is the distillation of the coal by means of the apparatus shown in Plate 1, of which the following is a description:—

Retort.

A is the retort, of a D shape, 18 inches long from the mouth-piece to the blank end, 5 inches in diameter, and 5 inches high. This retort is made of cast-iron, $\frac{3}{8}$ths of an inch thick, and capable of taking at a charge 2·24 lbs. of coal, or the $\frac{1}{1000}$th part of a ton. The heat from the furnace, which is fired with coke, passes along the bottom of the retort, which is exposed to its direct action, through openings at the end, back again, along the sides towards the mouth-piece, and, lastly, along the top to the chimney *b*. This chimney is provided with a suitable damper, and it has been found by actual experiment that a uniform heat can be obtained by this mode of setting, which all carbonizers know to be a very necessary condition to the proper and successful distillation of coal.

In the setting of the retort, I would, of course, prefer to construct the oven entirely of fire-bricks; but as, in some establishments, this method might not be convenient, an iron casing, lined with fire-brick, may be adopted, by which means both convenience of form and durability are secured.

Condenser.

The condenser (B) is of the ordinary form, consisting of $1\frac{1}{2}$-inch sheet tin pipes, arranged in a vertical manner, and attached to a box divided into compartments. Each of these compartments is provided with a brass stop-cock, so that, after the whole of the gas has passed over from the retort to the gas-holder, on opening the stop-cocks, the whole of the tar, liquor, or other condensable products, will run into the receivers *c*, *c*, and by this means the exact quantities of these constituents of the coal under examination are ascertained.

Purifier.

The purifier (C) is circular in form, made of stout sheet tin, and provided with a water-joint and cover in the usual way, the cover being held down by the lugs *d*, *d*. It is, of course, adapted to receive lime, oxide of iron, or any other material the experimentalist may wish to use as a purifying agent. This purifier is supplied with the necessary connexions, and a bye-pass cock, so that foul or unpurified gas may pass into the gas-holder when it is required to ascertain the quantity of carbonic acid, ammonia, or sulphuretted hydrogen, there may be in the sample of coal experimented upon.

Gas-holder.

The gas-holder (D) is 30 inches in diameter, and is capable of containing 20 cubic feet of gas. It is provided with counter-balance weights, so that during the carbonization of the coal and the consequent passage of gas to the holder, by a proper adjustment of the weights, all unnecessary pressure may be taken off the retort. The scale attached to the column of the gas-holder is so divided that it shows at once, by inspection, the quantity of gas produced from a ton of coals. There is also an outlet-pipe, with a brass stop-cock attached, in immediate communication with the photometer, to determine the illuminating power. The small $\frac{3}{8}$ brass cock in the crown of the holder, with india-rubber pipe attached, is for the purpose of taking off a sample of the gas to be tested in the eudiometer tube, to be described hereafter.

DISTILLATION OF COAL.

Distillation of Coal.

Before proceeding to charge the retort, see that the previous contents of the gas-holder are well blown out, and the holder landed on the bottom of the tank; then open the whole of the cocks between the gas-holder and the retort. When the retort is at a bright red heat, have the lid well luted with clay or lime, weigh the charge of coal, put it into the scoop, drive it briskly home, and secure the lid as quickly as possible. Now add a sufficient number of weights to the counter-balance, so as to produce a vacuum of about half an inch on the gauge attached to the gas-holder. When the charge is worked off, which will be seen when the gas-holder ceases to rise, shut off the inlet cock, and open the small brass cocks on the condenser, allowing the tar and liquor to escape into the reservoirs appointed for them. Remove sufficient weight from the counterbalance to bring the water level in the gauge attached to the gas-holder, and then read off the quantity of gas made, on the scale attached to the column. Remove the lid from the retort, and having drawn the coke and allowed it to cool in the open air, weigh it, and put it on one side for further examination.

CORRECTION OF BULK FOR TEMPERATURE AND PRESSURE.

Correction of Bulk.

In consequence of the extreme facility with which aeriform bodies are affected by variations in the temperature and pressure, these must always be taken account of in speaking of their volumes. It has therefore been customary to reduce them to what is called mean temperature and pressure, the mean temperature being 60 degrees Fahrenheit, and the mean pressure sufficient to balance 30 inches of mercury. This is the most convenient standard and the one usually adopted, although, by Act of Parliament, the temperature at which the specific gravity of spirits is determined, and weights and measures adjusted, is 62°. First, as to pressure:—the bulk of a given quantity of gas or any aeriform body, increases or decreases inversely as the pressure.

Suppose, for instance, it is required to know what volume 1,000 cubic feet of gas, at 29 inches barometrical pressure would occupy, at 30 inches—then,

$$\text{As } 30 : 29 :: 1{,}000 : 966\tfrac{2}{3};$$

that is to say, 1,000 cubic feet at 29 inches pressure would be reduced to $966\frac{2}{3}$ feet at 30 inches pressure. Next, as to temperature:—Dalton and Gay Lussac ascertained that 1,000 feet of air, when raised from 32° to 212°, expanded 375 feet, so that 1,000 feet at 32° occupied 1,375 feet at 212°; that is, an increase of temperature of 180° (the difference between 212° and 32°) increased the volume 375 feet, or 2·083 feet for every degree. If, now, 1,000 be divided by 2·083, the quotient will be 480, from which it appears that gas expands $\frac{1}{480}$th the volume it occupied at 32° for every increase of one degree of heat. Suppose, for example, we require to know what volume 1,000 cubic feet at 70° would occupy at 60°, we must bear in mind that it is not $\frac{1}{480}$th part per degree of the observed volume at 70°, which is to be deducted, but $\frac{1}{480}$th part of the volume which 1,000 cubic feet at 70° would occupy at 32°. Now, 480 parts at 32° become 481 at 33°, and increase one part for every degree; so that at 60° it would become $480+28=508$ parts, and at 70°, $480+38=518$ parts; then, by the following proportion, we obtain the required volume—

$$518 : 508 :: 1{,}000 : 980{\cdot}7,$$

which is popularly expressed in the following manner:—480 plus the difference between 32° and the observed temperature, is to 480 plus the difference between 32° and the standard temperature, as the observed volume of the gas is to the required volume of the gas.

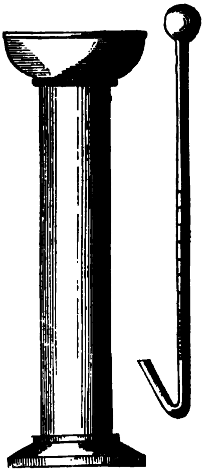
The late Mr. Alexander Wright, of Millbank Street, has published a table with his specific gravity apparatus, which is exceedingly useful in reducing the volume of a gas to the standard temperature and pressure. This table is inserted in his *Analysis of Gas for Practical Men*, and I would advise those of my readers to purchase it who do not wish to go through the calculations explained above.

We next proceed to examine the gas in the gas-holder, and I cannot too strongly insist upon the necessity of operating upon the gas in the gas-holder as soon as possible after it has come over from the retort; for if left too long, the gas being in contact with so large a surface of water, a considerable proportion of the hydrocarbon vapour will be absorbed, and a great deal of the ammonia present abstracted, in consequence of its rapid absorption by water. After gas has been standing in the gas-holder for 12 hours, I have found a diminution in illuminating power of 23 per cent. from this cause.

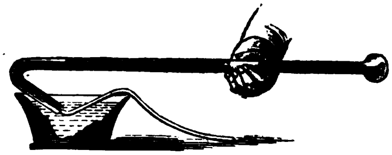
ANALYSIS BY THE EUDIOMETER TUBE.

Eudiometer.

First, we will determine its constituents by means of the eudiometer tube.

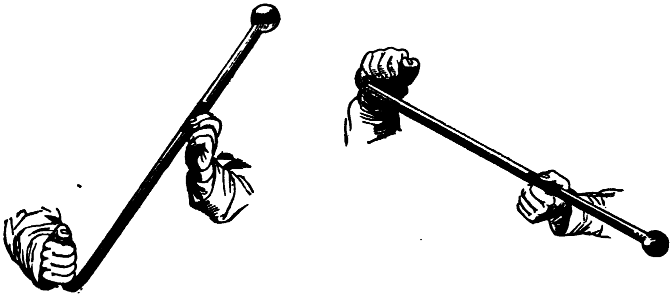


The condenser. The eudiometer.



The position in which the eudiometer may be held when filling it with gas by means of a small india-rubber tube.

Hydro-carbon vapours. Remove a sufficient number of weights from the counter-balance, so as to give about one inch pressure on the gas-holder. It is generally the custom to fill the tube with water, and then to pass into it the small india-rubber pipe attached to the cock in the crown of the gas-holder, and thus fill the eudiometer with gas by the displacement of the water; but, in consequence of the rapid absorption of sulphuretted hydrogen and carbonic acid by water, I consider it much better to pass the flexible tube quite into the bulb of the eudiometer when fillėd only with the ordinary atmospheric air, and to let the gas blow off for some seconds, so as to displace the whole of the air, and then to withdraw the india-rubber pipe under water. It is generally advisable to fill the tube about one division beyond zero, so as to allow for its condensation. When thus filled with gas, place the eudiometer in the condenser, and allow it to cool; upon removing it, see that the gas is exactly at zero, and if not, add more or let some out, as the case may be. Now pour into the open end a drop or two of bromine,* and taking care that the tube is quite full of water, cover it with the thumb and well agitate, allowing the bromine and water to pass freely from one end to the other; dense red fumes will rise, which is the vapour of bromine, and these combine with the hydro-carbon vapours, the light-giving principle of the gas. Now bring the water into contact with the thumb again, and place the hand containing the tube under water; remove the thumb, and water will rush into the tube to take the place of the condensed matter. Now



These engravings show the position of the operator's hands in analyzing gas by means of the eudiometer.

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* If too much bromine be used, the vapour from it will force the water out of the tube when the thumb is removed, and thus render the experiment useless.

add a small quantity of caustic potash and agitate as before, this will condense the excess of bromine. The open end of the tube is then to be held about half-an-inch below the surface of some clean water. The liquid in the eudiometer containing bromine and potash is of much higher specific gravity than pure water, it will therefore fall rapidly, and its place will as rapidly be taken by the clear fluid in which the tube is partially immersed. When this action has ceased, the eudiometer is to be again placed in the condenser for some seconds; upon its removal, read off the amount of condensation on the scale attached, and this reading, which varies greatly with different kinds of coal, is called hydro-carbon vapours, condensable by bromine. Now pour off some of the liquid, and add as much of solution of the proto-chloride of copper and muriatic acid as will be sufficient to fill the short leg of the tube; agitate as before, and then remove the thumb under water; allow the liquid in the eudiometer to be displaced by clean water, and then place it in the condenser; upon its removal, read off the scale, and this will be the percentage of carbonic oxide in the gas.

Carbonic oxide.

The remaining contents of the eudiometer are light carburetted hydrogen.

Sulphuretted hydrogen, and carbonic acid.

The above method of analysis will apply equally to purified or unpurified gas; but with foul gas, before going through the processes referred to above, the following means must be adopted in order to ascertain the percentage of carbonic acid and sulphuretted hydrogen:—

The tube is to be filled with foul gas, and condensed in precisely the same way as for clean gas; but instead of adding bromine, the first test will be a solution of the sulphate of copper; this will condense the sulphuretted hydrogen, the percentage of which will be read off as before: next add a few drops of strong solution of caustic potash, and, proceeding carefully in all the details as before, the percentage of carbonic acid in the gas will be determined; the bromine can now be added, and the remainder of the operation proceeded with as for clean gas. The whole of this should be gone through three times, and the average taken, in order to insure accuracy in the results.

In speaking of the condensation of the hydro-carbon vapours in coal gas by means of bromine and other agents, I ought not to omit to mention that there is a substance which will effect this object quite as successfully as bromine, and it is one which at first sight, we should hardly expect to have this peculiar property. In the winter of 1860–1861, Mr. F. J. Evans caused a naphtha box to be put up at the gas-works in Horseferry Road, for the purpose of improving the illuminating power of coal gas, when it was found that the photogenic power of the gas was very much decreased after passing through the naphtha, a circumstance which was at once attributed to the low state of the temperature, the thermometer at the time being below the freezing point; and, upon using naphtha instead of water in the eudiometer, it was found that the condensation was precisely the same as with bromine. Now, although it is quite clear that the naphthalising of gas depends partly on temperature, and partly on the mere mechanical effect produced by the gas passing over or through the naphtha; yet the condensation of the hydro-carbon vapours by this means does not seem to depend upon temperature at all, for, having made a great many experiments with the intention of setting this question at rest, I have invariably found that at temperatures ranging from 28° to 60° Fahrenheit, the condensation by naphtha has been identical with that by bromine, when the specific gravity of the naphtha was above ·800.

The same effect may be produced by using turpentine, olive oil, or, in fact, any oleaginous body. Coal-tar does it likewise, so also does pitch granulated with sawdust or fine sand—the gas being allowed to pass through, it is deprived of its hydro-carbon easily.

It may be as well, perhaps, in this place to remark, that the specific gravity of the hydro-carbon vapours condensable by bromine vary very much with the different kinds of bituminous and Cannel coals. Mr. Lewis Thompson states, in his treatise on the chemistry of gas lighting, published in vols. 2 and 3 of the *Journal of Gas Lighting*, that the specific gravity of the light-giving matter in Newcastle coal gas ranges from 2·80 to 3·3; and, in the table annexed, it will be seen that, in the Cannel coals, it ranges from 1·21 to 2·28.

The following results were obtained by Mr. F. J. Evans, of the Westminster station, and in each case three distinct experiments were made:—

Name of Cannel.	Gas per Ton.	Condensation per cent. by Bromine.	Specific Gravity of Gas.	Specific Gravity of condensed matter.	Photogenic Power, Candles.	
					Actual.	By Analysis.
Boghead	15,000	30·	·752	1·21	37·75	36·30
Lesmahagow, No. 1	13,500	16·	·642	1·64	27· 1	26·24
Lesmahagow, No. 2	13,200	17·	·618	1·43	24· 8	24·31
Capeldræ	14,400	16·5	·577	1·29	19·75	21·28
Arniston	12,600	17·0	·626	1·40	22·50	23·80
Ramsay	10,300	12·5	·548	1·82	21·40	22·95
Wemyss	14,300	14·5	·580	1·87	24·50	27·11
Kirkness	12,800	10·2	·562	1·95	21·20	19·88
Knightswood	13,200	9·5	·550	2·28	19·00	21·66
Ince Hall	11,400	11·5	·528	1·77	20·00	20·35

From an inspection of this table, it will be at once perceived that the amount of condensation by bromine multiplied by the specific gravity of the condensed matter, gives the photogenic power by calculation, which corresponds very nearly with the actual results obtained in the photometer.

The following table, for which I am also indebted to Mr. F. J. Evans, shows the yield of bituminous coal, and illuminating power of the gas:—

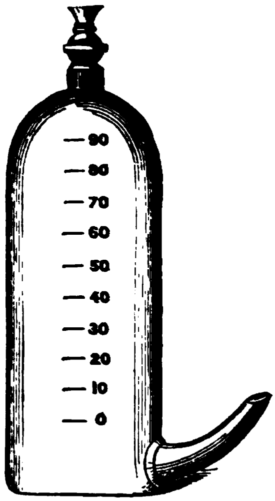
Name of Coal.	Gas per Ton.	Illuminating Power, Candles.	Specific Gravity of Gas.	Condensation by Bromine.
Pelton	11,000	14·0	·430	4·5
Do. Cannel	11,500	18·5	·520	10·5
Leverson	10,800	12·5	·425	4·0
Do. Cannel	11,600	18·0	·523	10·0
Washington	10,000	14·0	·430	5·0
Do. Cannel	10,500	18·0	·500	10·5
Pelaw	11,000	12·75	·420	4·5
New Pelton	10,500	12·00	·415	4·75
Dean's Primrose	10,500	13·5	·430	5·0
Garesfield	10,500	11·5	·398	3·75
Gasforth	10,000	12·0	·402	4·0
West Hartley	10,500	12·5	·420	4·2
Hastings' Hartley	10,300	12·5	·421	4·3
Blenkinsopp	9,700	14·0	·450	6·0

SPECIFIC GRAVITY OF THE VAPOUR CONDENSED BY BROMINE.

Before proceeding further, I shall describe, as shortly as I can, the method adopted by Mr. Lewis Thompson for ascertaining the

Specific gravity of vapour condensed by bromine.

specific gravity of the vapour condensed by bromine. The specific gravity of the gas must be first carefully ascertained in the way hereafter to be described. Let us suppose it to be ·752. A large glass vessel, about 18 inches high and 4 inches in diameter, is provided with a closely ground stop-cock at the top and a curved pipe at the bottom, similar to the open end of the eudiometer tube. This vessel is divided off into 100 parts, and a scale engraved upon it. Having now filled it with water, close the stop-cock and introduce the gas through the open-ended curved pipe; let the gas rush into the vessel till the water line is brought down to zero; condense as when using the ordinary eudiometer tube; put in a few drops of bromine, agitate, condense by potash, pour off the water in the vessel through the curved pipe by displacement, condense, and then carefully note the scale. Suppose the condensation has been, as in the case of Boghead, on the above table, 30 per cent.; the next process will be to ascertain the specific gravity of the gas remaining in the vessel. For this purpose a glass ball is provided, having a ground stop-cock, fitting exactly into the stop-cock on the top of the vessel. Having balanced the ball in a very delicately-constructed balance, exhaust the air out of it by means of an air-pump, and then weigh again; the number of grains required to bring the balance into equilibrium represents the weight of the air abstracted. Now attach the ball to the vessel by means of the two stop-cocks, and having immersed the vessel in water, open the cocks gently and the ball will be immediately filled with gas; weigh again carefully, and the number of grains will represent the exact weight of the gas introduced into the ball, then the weight of air abstracted is to the weight of gas introduced as unity is to the specific gravity of the gas, which, in the case above referred to, was ·555—the average of three experiments.



We now have the following results:—

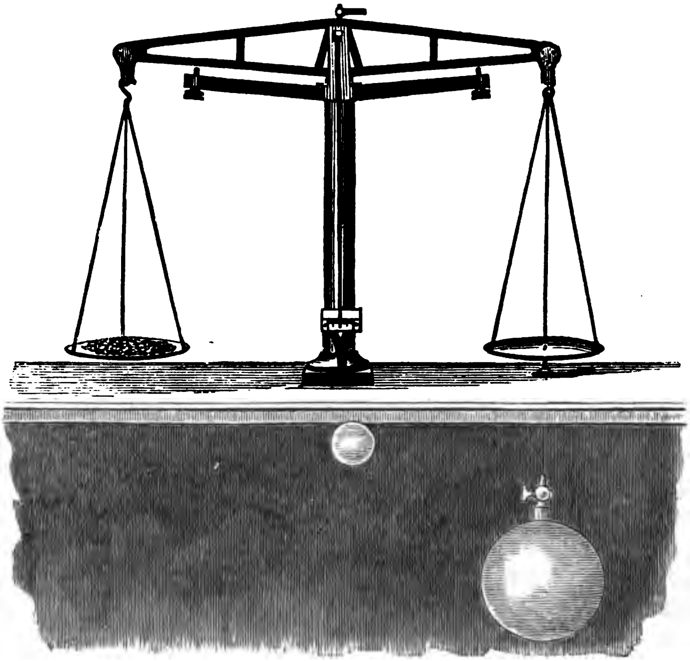
Original specific gravity of gas ·752 ; or
Specific gravity of 100 volumes ·752
Ditto 70 do. ·555
then 100 × ·752 = 75.2
70 × ·555 = 38·90

Specific gravity of remaining 30 parts 36·30

and 36·30 divided by 30 = 1·21, the specific gravity of the matter condensed by bromine.

From this it will be seen how exceedingly laborious some of the investigations are in the analysis of gases, especially in forming an accurate table of the constituents of the various kinds of coal.

SPECIFIC GRAVITY OF GAS.



Balance, with glass globe suspended from under side of the pan.

I will now proceed to describe the two processes most usually employed for determining the specific gravity of a gas: and first,

Specific gravity of gas. by means of a glass globe. To carry out this experiment accurately, a good air-pump is absolutely necessary; a very light globe, made of hard German glass, is provided, with a stop-cock made of the new metal, aluminium, this being the lightest of all known metals. The capacity of this ball is about 100 cubic inches; having adjusted the balance, weigh the globe accurately to the fractional part of a grain, and then remove it to the air-pump; having exhausted the air, weigh it again, and the number of grains and tenths of a grain represent the weight of the air abstracted. Suppose it takes thirty-one; now fill the ball with gas by attaching it to the cock in the top of the gas-holder, and, opening it very carefully, weigh again, and the number of grains represents the weight of the gas introduced. Suppose it takes thirteen; then—

As 31 : 13 : : 1 : ·419,

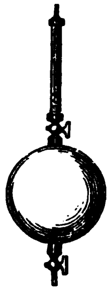
The specific gravity of the gas is therefore ·419, air being taken at 1·000; and as 100 cubic inches of pure and dry atmospheric air weigh at mean temperature and pressure 31·0117 grains, the weight of 100 inches of the gas can be easily determined; for,

As 1·000 : ·419 : : 31·0117 : 12·993;

that is, as the specific gravity of air is to the specific gravity of the gas, so is the weight of 100 inches of air to the weight of 100 inches of the gas, and from this result the weight of any quantity of the gas can of course be determined.

As there is some little difficulty in attaining a correct result by the above method, the late Mr. A. Wright, of Millbank Street, proposed to use a balloon, whose capacity should be 1728 cubic inches, or one cubic foot. There is a small ivory stopper, provided with a brass pan for the reception of weights, each of which represents the weight of one thousandth part of a cubic foot. Having filled the balloon with gas and inserted the stopper, as many weights are to be added as will just keep the whole apparatus from rising in the air; if now, the weights put into the pan, say 169, be added to the weight of the balloon and car in the same standard, say 412, the aggregate number, 581, would represent the buoyancy of the gas, or the tendency it had to rise in the atmosphere; and, as the specific gravity of the air is 1·000, if from this we deduct the above ·581, we have the remainder, ·419, as the specific gravity of the gas. This is a very cheap and convenient apparatus, and can be easily used by anyone, and certainly is not open to the objections urged against the method described above, which are, the small quantity of gas operated upon, and the great weight of the flask compared with the gas it contains.

Dr. Letheby's method of ascertaining the specific gravity of gas, is as follows:—He uses a glass globe, of about six inches in diameter, with a double neck. The two necks are opposite each other, and are fitted with small caps and very small stop-cocks. One of the stop-cocks screws into a gas-pillar, and so supports the globe; the other carries a cap, with a glass tube about half an inch in diameter and seven inches long. This tube contains a thermometer, and is fitted at the opposite end with a jet for burning the gas.



The globe, with the stop-cocks attached but without the tube, is accurately balanced while in an exhausted state, and a counterpoise weight is provided. The exact weight of the globe when full of air, at 60° Ft., and 30 Ba., is ascertained, and engraved on the globe.

In practice, the globe is always attached to the gas-pillar, and therefore gas is constantly passing through it, so that it is always full of gas ready for weighing. When this is required, the gas is shut off, by first turning the *lower* stop-cock, and then, a moment after, the upper one, so that the globe at the time of weighing has not the contained gas at the pressure in the main, but at the atmospheric pressure. It is then suspended from the beam of the balance, and its exact weight determined. By a simple rule of three, the specific gravity of the gas is ascertained,* and correction is then made, in the usual manner, for temperature and barometric pressure.

---

* Say, the weight of the globe, when full of air, is 60 grains more than the counterpoise of the globe in its exhausted state, and that when taken from the gas-pillar, and is full of gas, the weight of the globe is 25 grains—then, as 60 : 1,000 (the sp. gr. of air) : : 25 : 417 (the sp. gr. of the gas).

The advantage of the apparatus is, that it requires no exhausting, but is always ready for experiment.

CORRECTIONS FOR MOISTURE.

Moisture. It is sometimes necessary, in making very delicate experiments on coal gas, to allow for moisture or aqueous vapour present, for it is a well-established fact that gas absorbs a certain quantity of aqueous vapour, proportional to the temperature when standing in the gas-holder in contact with water. Suppose a gas, for instance, to be saturated with moisture from the above cause, its weight, and therefore the determination of its specific gravity, would be affected to a certain extent by the quantity of moisture present, the vapour of water being much lighter than the gas. The weight of the moist gas must, therefore, be first ascertained in the manner described above; from this the weight of the known volume of aqueous vapour must be subtracted, and the remainder will represent the weight of the dry gas.

The following table, which is founded upon the experiments of Dalton and Ure, exhibits the proportions by volume of aqueous vapour existing in any gas standing in contact with water at the corresponding temperatures, and at mean barometric pressure :—

Degrees.	Volume of Aqueous Vapour.	Degrees.	Volume of Aqueous Vapour.	Degrees.	Volume of Aqueous Vapour.
40	·00933	54	·01533	68	·02406
41	·00973	55	·01586	69	·02483
42	·01013	56	·01640	70	·02566
43	·01053	57	·01693	71	·02653
44	·01093	58	·01753	72	·02740
45	·01133	59	·01810	73	·02830
46	·01173	60	·01866	74	·02923
47	·01213	61	·01923	75	·03020
48	·01253	62	·01980	76	·03120
49	·01293	63	·02050	77	·03220
50	·01333	64	·02120	78	·03323
51	·01380	65	·02190	79	·03423
52	·01426	66	·02260	80	·03533
53	·01480	67	·02330		

In using this table, which embraces a range of 40° Fahrenheit, opposite the observed temperature of the gas will be found the proportion in volume of aqueous vapour at a pressure of 30 inches. This volume must be corrected to the mean temperature of 60°, and then deducted from the volume of the gas corrected to mean temperature and pressure; the remainder will be the volume of dry gas. For instance: suppose 100 cubic inches of gas weighs, in the glass ball before referred to, 17 grains, the temperature at the time being 70°, and the barometer 30·2 inches, by reference to the table, opposite 70° will be found ·02566, as the portion of vapour present at that temperature, and ·02566 × 100 = 2·566 inches, the total quantity in 100 inches: this must be reduced to the mean temperature, as before explained:—

$$480 + 38 : 480 + 28 :: 2{\cdot}566 : 2{\cdot}516.$$

Now to ascertain the volume of the gas:—100 inches at 70° will be reduced to 98·069 inches at 60°; for

$$480 + 38 : 480 + 28 :: 100 : 98{\cdot}069;$$

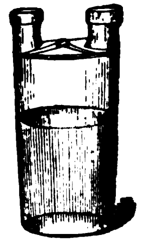
and this amount, corrected for pressure, will become 98·722; for

$$30 : 30{\cdot}2 :: 98{\cdot}069 : 98{\cdot}722;$$

and if from 98·722 be deducted 2·516, the remainder, 96·206, will represent the volume of dry gas at mean temperature and pressure. Now, it has been ascertained, with perfect accuracy, that a cubic inch of permanent aqueous vapour, at a temperature of 60° and barometer 30 inches, weighs 0·1929 grains; therefore, 2·516 inches multiplied by ·1929 will equal ·4853, and this subtracted from 17 grains (the whole weight), will leave 16·5147 grains—which will be the weight of 96·206 inches of dry gas; and, by a simple proportion, it will therefore be found that 100 inches of such gas at mean temperature and pressure will weigh 17·165 grains. The best method that can be adopted to dry the gas, is to pass it through a glass tube about 24 inches long and ¾ inch internal diameter, filled with pieces of perfectly dry chloride of calcium, which by its strong attraction for moisture rapidly abstracts the whole aqueous vapour present. The gas must not pass through this tube too quickly, about ten minutes being required to operate successfully upon 100 inches of gas. When the chloride is not perfectly dry, it may be fused in a common retort, and used as soon as cold.

AMMONIA.

Ammonia.



The quantity of ammonia still in the gas is next to be ascertained. For this purpose, a bottle with two necks, commonly called a "Woulfe's bottle," is employed. Fill the bottle about half full of distilled water, and then add 49 grains of sulphuric acid, specific gravity 1·845. This quantity of acid will saturate 17 grains of ammonia; solution of litmus is now to be added till the liquid in the bottle assumes a bright red colour; a small tube, passing through a cork in one neck of the bottle and reaching nearly to the bottom, is connected with the gas to be examined, and a similar tube from the top of the bottle, passing through the other neck, is connected with the inlet of an experimental meter. The gas is made to pass through the whole apparatus, and the ammonia it contains is arrested by the acid solution in the bottle. As soon as the solution assumes a purplish colour it may be taken as neutralized, and the quantity of gas passed through is to be carefully noted by means of the meter. The number of cubic feet indicated contains as much ammonia as would saturate the whole of the acid solution in the bottle. Of course, this would be a quantitative analysis of the ammonia in the gas; but, in order merely to detect the presence of this alkali, it is sufficient to allow a jet of gas to blow on a piece of turmeric or reddened litmus paper moistened—if ammonia be present, the turmeric is turned dark red and the reddened litmus a deep blue colour. The Metropolis Gas Act of 1860 enacts, that the gas supplied to the inhabitants of London "shall, with respect to its purity, be so far free from ammonia and sulphuretted hydrogen, that it shall not discolour either turmeric paper or paper imbued with acetate or carbonate of lead, when those tests are exposed to a current of gas issuing for one minute under a pressure of five-tenths of an inch of water."

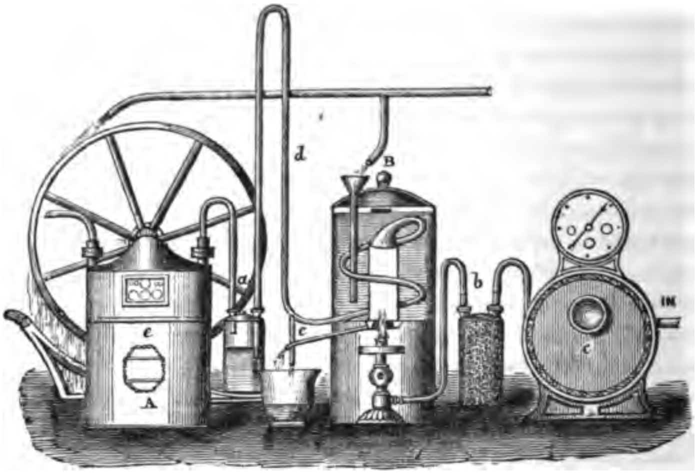
BISULPHIDE OF CARBON.

The next subject to which attention must be given is one of considerable importance: it is the process to be employed

Bisulphide of carbon.

for the detection of bisulphide of carbon in the gas. As I have remarked above, all coals contain a certain percentage of iron pyrites—which is principally bisulphuret of carbon. To decompose this a white heat is required; and it is, therefore, at the latter part of the charge, when the retort is at its highest heat, that the principal part of the bisulphuret of carbon is generated. Every precaution ought to be taken by gas engineers to prevent this highly injurious compound from being produced during the distillation of the coal, as no practical method has yet been discovered for its removal. Even with the greatest care and attention on the part of the carboniser, to have well-regulated heats, the presence of bisulphide of carbon will sometimes be detected. In order to prevent this evil, as far as practicable, it is enacted in the above-mentioned Act of Parliament, that, as far as the gas supplied to the metropolis is concerned, it "shall not contain more than twenty grains of sulphur in any form in one hundred cubic feet of gas." Several different methods are adopted by chemists to ascertain the quantity of this compound in coal gas; those to which I shall refer are by Mr. F. J. Evans, Dr. Letheby, and the late Mr. A. Wright.

On the next page is an engraving of the apparatus, by Mr. Evans:—**A** is a motive power dry meter—that is, a meter which is driven by a water-wheel or clockwork, and, by the alternate contraction and expansion of the diaphragms, it acts as a pump, drawing the air or gas in at the inlet, and discharging it at the outlet. **B** is a condenser; in the centre of this condenser is a white metal chimney, similar to the 7-inch glass chimney of an ordinary Argand burner. This chimney has a funnel-shaped top, connected to a ⅝ spiral tin pipe, arranged in coils inside the condenser, which discharges itself at the bottom into the pipe *c*, which leads through the swan neck *d* to the inlet of the meter; at the bottom of this chimney is fixed a narrow gallery with an outlet-pipe for the purpose of collecting all the moisture condensed in that part of the apparatus. A Bunsen lava burner is provided with a white metal dish, through the centre of which it is made to pass, so that the point of combustion is immediately above the dish; this burner is attached to the outlet of the experimental meter **C**. The gas to be tested is, of course, made to pass through this experimental meter; and it is advisable sometimes to pass the gas through a small scrub-



ber, as shown at *b*, filled with pebbles moistened with a weak solution of sulphuric acid and water, before entering the meter, so as to secure the complete absorption of all the ammonia. At *a* is also shown a Woulfe's bottle, containing a solution of caustic potass, for the purpose of arresting the carbonic acid produced by the combustion of the gas. Let us suppose the whole of this apparatus connected as above described, and that we now wish to determine the quantity of sulphur compounds in a given quantity of gas. The condenser must be filled with cold water, which is allowed to pass through the inlet-pipe quite to the bottom, the water at the surface being carried away through the overflow-pipe. The water is then turned on to the water-wheel; this sets the meter to work, which draws the air through the condenser. Care must be taken not to turn the water on too strong, as it is only necessary to maintain a very gentle current. The small dish attached to the burner is filled with liquor-ammonia, and the gas ignited. The burner is now placed under the condenser, so that the flame may pass up the chimney; the meter being in action, the products of combustion are drawn through the spiral pipe, condensed, and then flow through the small pipe at the bottom of the swan-neck into a receiver—the supply of ammonia to the burner is easily maintained by allowing it to drop from a small glass syphon-pipe into the dish surrounding the burner. In this way the gas is allowed to burn for seven or eight days, at the rate of about half a cubic foot per hour, until about 100 feet have been consumed. During the combustion of the gas, the following changes take place:—the hydrogen of the gas unites with the oxygen of the atmosphere, and forms water; the carbonaceous constituents of the gas also unite with oxygen and form carbonic acid; and lastly, the sulphur and ammonia unite with the oxygen and form sulphate of ammonia. The liquid products of combustion, being carefully collected, will be found to weigh from 350 to 400 grains for every cubic foot of gas burnt. These are to be saturated with pure nitric acid, to drive off the carbonic acid present, the evolution of which is facilitated by applying heat. The carbonic acid being all driven off, the liquid is now to be treated to excess with a solution of nitrate of baryta or chloride of barium. A white precipitate of the sulphate of baryta is immediately thrown down, and, after being allowed to stand for some time in a precipitating glass, the supernatant liquor is to be carefully poured off, and the salt collected on a counterpoised filter; it is then washed with boiling distilled water, dried and weighed in the manner hereafter to be described for testing the presence of sulphur in the coke. Every 117 grains of sulphate of baryta so produced indicate 16 grains of sulphur; consequently the quantity of sulphur present in any form in 100 feet of the gas can be at once calculated.

The ammonia is employed in this apparatus to arrest the sulphurous acid vapour produced by the combustion of the gas. The vapour of ammonia combined with the vapour of the acid, is condensed, and flows with the water into the receiver. If ammonia were not employed, a great part of the sulphurous acid would escape in the form of gas from the outlet of the condenser, its presence being easily detected by holding a piece of moistened litmus paper over the mouth of the pipe—the paper being first reddened, and then turned nearly white.

The apparatus employed by Dr. Letheby for determining the amount of sulphur present in gas, is represented by the engraving on the next page. The gas is allowed to pass first through a meter, and then into a bottle filled with pebbles moistened with a solution of sulphuric acid.* The inlet pipe to this bottle is allowed to

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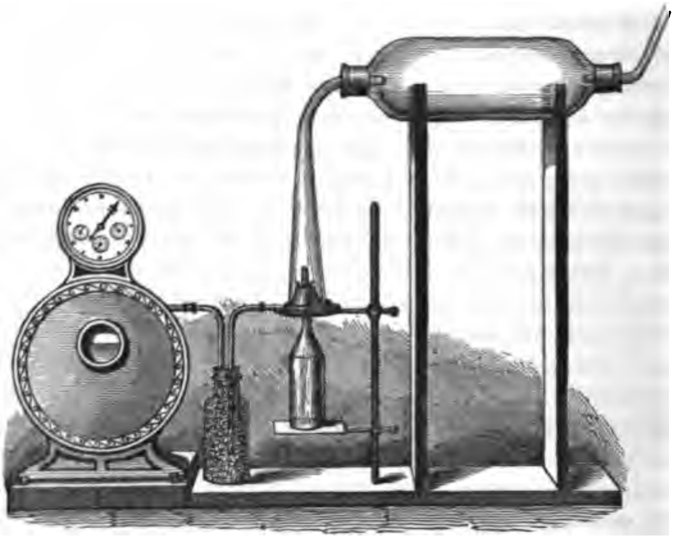
* The solution is prepared of a given strength, so that 100 grains of the solution should be exactly neutralised by 54 grains of recently-ignited carbonate of soda, or

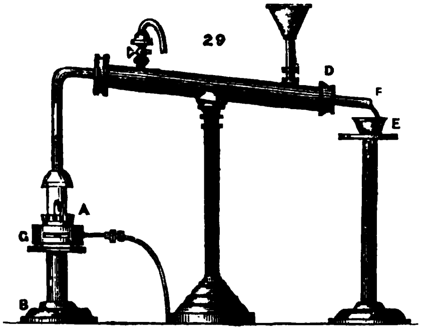


pass one inch only through the cork. The outlet passes through the cork from the bottom of the bottle. The gas is thus forced through the pebbles from the top, and no accumulation of salt takes place about the inlet pipe, which would be the case if it passed through the cork to the bottom of the bottle. The gas, by this means purified of its ammonia, is consumed at the rate of about half a foot per hour in a Leslie burner, which is placed under the long funnel-shaped tube, as here represented. This tube is connected to one end of a large glass condenser, the other end of which is furnished with a piece of glass tube about four feet long, joined in such a manner that any products of combustion condensed in it will flow back into the large receiver. The means by which ammonia is supplied to this burner are the following:—A wide-mouthed bottle filled with the strongest liquor ammonia is placed immediately beneath the burner, and a funnel, with a short tube attached to it, is placed over the bottle in an inverted position. This short tube passes through the centre of the burner, so that the end of it is about two inches above the top of the flame. The draught produced through the whole apparatus when the burner is alight, is

by 17 grains of ammonia. The solution has a specific gravity of about 1397, and is made by adding 20 fluid ounces of strong commercial sulphuric acid to 30 fluid ounces of water.

sufficient to evaporate the ammonia in the bottle which is discharged through the tube in the centre of the burner. Immediate combination ensues between the ammonia thus evaporated and the sulphur products of the consumed gas. These, when condensed, are treated in the manner before described for determining the amount of sulphur.

The late Mr. Wright, of Millbank Street, also made an apparatus for effecting the same object; it consists of a glass tube bent at right-angles, and so arranged that one part of it acts as a chimney to the jet of gas, and the other part as a Liebig condenser. A small chamber for the ammonia is placed beneath the gas jet, and the products of combustion are collected as they flow from the end of the condensing tube.



ILLUMINATING POWER.

Illuminating power of Gas.

We will now proceed to examine the illuminating power of the gas by means of the photometer.

The photometer is, as its name implies, an instrument for determining the amount of light given by any illuminating agent, in terms of some other agent; and, as it is very important that the same standard should be adopted in all parts of the country, in order that the results of one operator may be compared with those of another, it may not be out of place to quote the Act of Parliament entitled, "An Act for better regulating the Supply of Gas to the Metropolis," dated 28th August, 1860. The 25th Clause of this Act provides, that, so far as London is concerned, "The quality of the common gas supplied by any Gas Company shall be, with respect to its illuminating power at a distance as near as may be of one thousand yards from the works, such as to produce from an Argand burner having fifteen holes and a seven inch chimney, consuming 5 cubic feet of gas an hour, a light equal in intensity to the light produced by not less than 12 sperm candles of six to the pound, each burning 120 grains an hour, and the quality of cannel gas supplied by any Gas Company shall, with respect to its illuminating power at the distance aforesaid, be such as to produce from a batswing or fishtail burner, consuming 5 feet of gas per hour, a light equal in intensity to 20 such sperm candles." It will be seen from this extract that the Act not only defines the quantity of gas, and the kind of burner, but it also specifies that the standard measure of illuminating power shall be a sperm candle, so made that it shall consume at the rate of one hundred and twenty grains of sperm per hour. It is quite true that this standard of comparison applies to the metropolis only, but, at the same time, so many advantages would result from the adoption of the same system all over the country, that little need be urged in its favour beyond the obvious benefit all interested in the analysis of coals would derive from the same method of testing the illuminating power of the gas being adopted by all experimentalists.

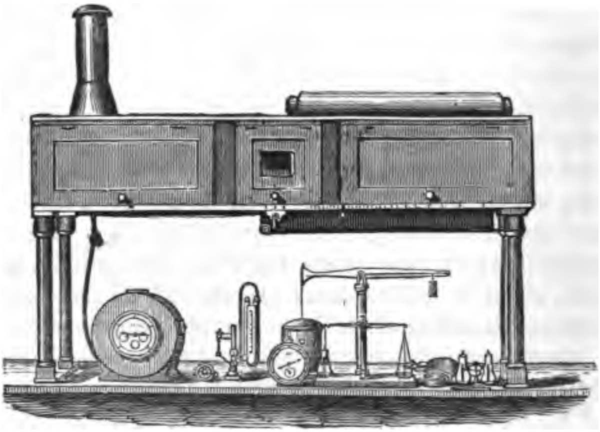
The construction of the photometer depends upon the well-known law of optics, that the quantity of light thrown upon any object by any luminous body is inversely as the square of the distance. In order to make this clear, let us suppose a disc of paper to be placed in a vertical position, one hundred inches from a candle, on the same level; if the candle be lighted, the paper will be illuminated on the side facing the candle, with a certain quantity of light; let the candle and the disc be now placed fifty inches apart, half the original distance, and the paper will be then illuminated with four times the quantity of the first position; if placed at thirty three and one third inches, or one third the original distance apart, the light will be increased to nine times and so on, as shown more clearly in the following table:—

If at 100 inches apart, the light be taken as 1.
at 50 inches or ½, it will be 4, the square of 2 being 4.
at 33⅓ inches or ⅓ it will be 3 × 3 = 9.
at 25 „ or ¼ „ 4 × 4 = 16.
at 20 „ or ⅕ „ 5 × 5 = 25, &c., &c.

In applying this beautiful law to determine the illuminating power of any light-giving agent, an instrument of most careful and accurate construction is absolutely necessary. The first photometer was made, I believe, by Count Rumford, who adopted the plan of adjusting the lights, at such a distance from an upright rod, that the shadow produced by each on a white screen should be equal. He then measured the distances of the lights from the rod, and the larger number of inches squared, divided by the smaller number squared, gave the illuminating power of the greater light in terms of the lesser. But this method soon gave way to a much more simple and accurate process, devised by Bunsen. If a piece of white paper be saturated with melted spermaceti, it becomes translucent, and if a spot be left untouched in its centre about the size of a shilling, we shall find that when examined by reflected light—that is, light from the same side as the observer—the disc will look white and the surrounding part dark; but if the observer shift his position to the opposite side, and examine the paper by transmitted light—that is, light from the opposite side of the instrument—the disc will appear dark, and the surrounding part light and translucent. Lastly, if two lights of equal intensity are placed one on each side of the paper, the disc will disappear, for then the light from one side neutralizes the light from the other, and there is no disposition to produce either effect. This is the principle of Bunsen's photometer, which, as originally constructed by Mr. King of Liverpool, consisted of a simple bar of wood placed with its edge uppermost, and firmly supported at both ends; the gas to be tested was burned at one end and the candle at the other, a circular disc of paper was fitted to a socket and made to slide freely up and down the bar, so that when placed in such a position that the light from the gas was equal to the light from the candle, the value of the gas in terms of the candle, might be read off on a scale attached. There are some drawbacks to this arrangement; in the first place it must be fixed in a room, the walls of which are painted a dead black, or the reflection from them would seriously interfere with the correctness of the result, and the eye would very soon become unable, from exposure to the bright light of the gas and candle, to detect any very delicate variations of shade on the disc. In order to obviate these objections, Mr. Evans, of the Horseferry Road Station of the Chartered Gas Company, suggested the employment of a long box lined with black cloth or velvet, as a substitute for the dark room, and this method was first used to test the light given by a gas lamp, when burning under ordinary circumstances in the street. This photometer, as manufactured by Mr. W. Sugg, is now used by all the metropolitan gas companies, and by nearly all the medical officers appointed by the various local boards of the metropolis, to test the illuminating power of the gas supplied by the several companies. No better proof could be given of the excellence and general convenience of this arrangement.

THE EVANS PHOTOMETER,

Photometer. as manufactured by Mr. Wm. Sugg, consists, as will be seen by the accompanying sketch, of a long box of wood. This box is made of the best pine, French polished. It is lined on the inside with black velvet, so as to prevent, as far as possible, reflection and radiation of light. A paper disc, prepared in the manner hereafter described, is fixed in a metal partition in the centre of the box, and a gas burner is placed exactly 50 inches from each side of the disc. A slot is made in the bottom of the box, extending from end to end, and in this slot a brass socket for carrying the candle is made to move freely backwards and forwards by means of an endless chain working over two pulleys attached to the bottom of the instrument at each end of the slot. A handle is attached to the pulley nearest to the centre, so that the operator,



The 50-inch box photometer, with meter, governor, pressure pillar, minute clock, candle balance, and holders, complete.

by turning this handle, can move the candle either way without taking his eye off the disc.

The distance from the disc to the burner is, in this case, a constant quantity; but the distance from the candle to the disc varies with the illuminating power of the gas. Let us call the latter distance x. Now, bearing in mind what has been said above, put the proposition thus:—

If (n) candles (the number to which the gas is equal) require 50 inches, what distance (x) is required for one candle? The equation is, therefore,

$$n : 1 :: 50^2 : x^2;$$

$$\text{or, } nx^2 = 50^2.$$

Suppose $n=9$, then

$$9x^2 = 50^2,$$

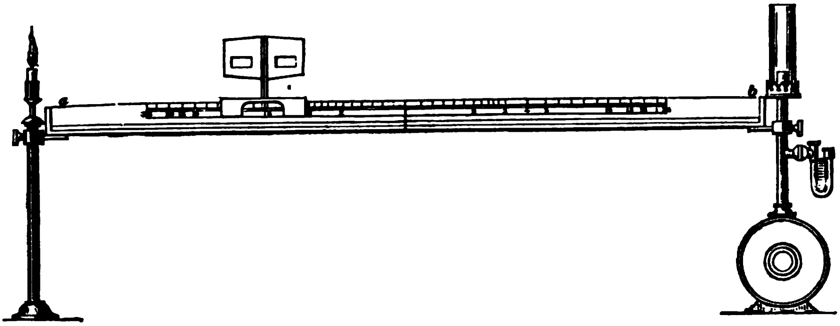
$$x^2 = \frac{50^2}{9}.$$

Extracting the root on both sides, we get

$$x = \frac{50}{3} = 16{\cdot}66 \text{ inches.}$$

That is, if the candle be $16\frac{2}{3}$ inches from the disc, the gas is equal to 9 candles; and so on, by substituting for n the numerical value of the gas in candles, the several points in the scale are determined.

As many of the 100-inch Bunsen photometers are still in use, it may not be quite out of place to show the way in which that scale is computed, for the information of our readers who are interested in that subject. Let us suppose a, b, to be the beam:—



In this case the gas, or the number of candles to which it is equal, multiplied by x^2, is equal to the candle or unity multiplied by $(100-x)^2$; or, putting it in the form of an equation, we have

$$nx^2=(100-x)^2$$
$$nx^2=100^2-200x+x^2;$$

or,

$$nx^2+200x-x^2=100^2$$
$$nx^2-x^2+200x=100^2$$
$$(n-1)x^2+200x=100^2$$
$$x^2+\frac{200}{n-1}x=\frac{100^2}{n-1}.$$

Completing the equation,

$$x^2+\frac{200}{n-1}x+\frac{100^2}{(n-1)^2}=\frac{100^2}{n-1}+\frac{100^2}{(n-1)^2}$$
$$=\frac{100^2(n-1)+100^2}{(n-1)^2}$$
$$=\frac{100^2n-100^2+100^2}{(n-1)^2}$$
$$=\frac{100^2n}{(n-1)^2};$$

and extracting the root,

$$x+\frac{100}{n-1}=\frac{100\sqrt{n}}{n-1};$$

that is,

$$x=\frac{100(\sqrt{n}-1)}{n-1}.$$

Having now found the value of x in terms of the candle, let us suppose the gas equal to 9 candles; then, substituting 9 for n in the above equation, we have

$$x=\frac{100(\sqrt{9}-1)}{9-1}=$$
$$=\frac{100(3-1)}{9-1}$$
$$=\frac{100\times 2}{8}=25 \text{ inches};$$

or, in other words, if the disc be 25 inches from the candle in the 100-inch beam photometer, the gas will be giving a light equal to 9 such candles—the gas being exactly three times as distant from the disc as the candle.

The Disc. The disc is made of the best white drawing paper, a circular spot being left opaque in the centre, and the external annulus rendered partially transparent by melted spermaceti. Considerable care is necessary in the preparation of these papers, so that the quantity of spermaceti may be perfectly uniform all over the surface. This is secured by a small machine contrived by Mr. Sugg, which effects its object admirably. The disc I prefer for my own use is one which was first suggested, I believe, by Dr. Leeson. It consists of three pieces of paper; a centre one made of cream-laid note paper, with a circular or star-shaped hole cut through it, about 1 inch in diameter, and two other pieces of white foreign post placed on each side of it. The advantage of this disc is its perfect uniformity of surface, and its being precisely the same colour on both sides; and in using it, instead of having to compare two slightly illuminated spots, as in the spermaceti disc, we only have to determine which disc presents the most distinctly-defined star, without reference to the colour of the surface. The only objection to be urged against the three thicknesses of paper, is the difficulty of securing perfect contact all over the surfaces.

Some practice is necessary in order to secure uniformity in photometrical observations, as the eye is easily deceived by the different colour of the light from the gas and candle—that from the gas being white, and that from the candle of a brown or yellow hue. By using two or three candles instead of one, a whiter light is obtained. In making an observation with the photometer to determine the illuminating power of a gas, I invariably adopt the following process:—First burn the gas well off, so that there may be none left from previous experiments in the meter or fittings. Adjust the burner by means of the micrometer cock and the small governor, so that the consumption may be at the rate of 5 feet per hour;* and then light the candle and place it in the balance. Stop the minute-clock attached to the meter as

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* It is absolutely necessary that the quantity consumed should be 5 feet, or as near as possible to that quantity; if a less quantity be consumed, and then reduced to the standard of 5 feet by a simple proportion, the result will be against the gas, as appears from the following table:—

Quantity Consumed.	Illuminating Power, as indicated by the Photometer.	Reduced to 5 feet per Hour.	Value of 1 foot of Gas in Standard Candles.
5·0 feet.	14·0 candles.	14·0 candles.	2·800
4·0 „	9·5 „	11·9 „	2·375
3·0 „	4·3 „	7·2 „	1·433
2·5 „	2·8 „	5·5 „	1·120
2·0 „	1·0 „	2·5 „	0·500

The burner employed to obtain these results was a 15-hole Argand burner, with a 7-inch chimney.

the bell rings, and when the candle is well alight and has formed a cup round the wick, balance it, and when exactly in equilibrium start the clock. Now remove the candle and socket, and place it in the photometer, and note the illuminating power, as indicated by the scale, every minute for ten minutes, or every half minute for five minutes. There are thus ten observations, which merely require to be added together, and the decimal point shifted one figure to the left, and the result is the average illuminating power. The candle, which must be extinguished at the end of the ten observations, is now removed with its socket and accurately weighed—the number of grains lost, multiplied by six (or by twelve, as the case may be), will give the grains consumed per hour. A simple calculation will now give the illuminating power of the gas in terms of the candle, reduced to the Parliamentary standard of 120 grains per hour. As an example, let us suppose that the candle has consumed 125 grains per hour; then, if 5 feet of gas has given a light equal to 13 such candles, it is obvious that it will equal more than 13 candles of 120 grains. Therefore, we have the following simple proportion:—

As 120 : 125 :: 13 : 13·54.

The illuminating power of the gas would thus be 13·54 standard candles.

Now, although the Act of Parliament already referred to, very properly enacts that the quantity of gas consumed shall be 5 feet; yet, from various causes, this rule is often deviated from in practice. Suppose the quantity to be 5·2 feet of gas, equal to 13·54 candles; then it is clear, that the light given by 5·2 feet would be greater than that from 5 feet, and we get the following proportion:—

As 5·2 : 5 :: 13·54 : 13·02.

In order to avoid these calculations, and facilitate photometrical observations, the following table is here added. To make quite clear the method of using it, which may not be so obvious from the rule appended, let us take the above-quoted observation, viz.,—5·2 feet of gas equals 13 candles of 125 grains. Now, under the column headed 125, and opposite the figures 5·2, will be found the number 1·00160, which, multiplied by 13, gives 13·02 as the corrected illuminating power in terms of the standard candle, which corresponds exactly with the figures given above.

This table is equally well adapted for both Cannel and Newcastle gas of any illuminating power.

GENERAL TABLE, CALCULATED FOR ONE CANDLE. (W. SUGG.)

Consumption of Gas.	GRAINS PER HOUR CONSUMED BY THE SPERM CANDLE.												
Feet per Hour.	110	111	112	113	114	115	116	117	118	119	120	121	122
4·5	1·01851	1·02777	1·03703	1·04629	1·05555	1·06481	1·07407	1·08333	1·09259	1·10185	1·11111	1·12037	1·12962
4·6	·99637	1·00543	1·01449	1·02355	1·03260	1·04166	1·05072	1·05978	1·06884	1·07789	1·08695	1·09601	1·10507
4·7	·97517	·98404	·99290	1·00177	1·01063	1·01950	1·02836	1·03723	1·04609	1·05496	1·06383	1·07269	1·08156
4·8	·95486	·96354	·97222	·98090	·98958	·99826	1·00694	1·01562	1·02430	1·03298	1·04166	1·05034	1·05902
4·9	·93537	·94387	·95238	·96088	·96938	·97789	·98639	·99489	1·00340	1·01190	1·02040	1·02891	1·03741
5·0	·91666	·92500	·93333	·94166	·95000	·95833	·96666	·97499	·98333	·99166	1·00000	1·00833	1·01666
5·1	·89869	·90686	·91503	·92320	·93137	·93954	·94771	·95588	·96405	·97222	·98039	·98856	·99673
5·2	·88141	·88942	·89743	·90544	·91346	·92147	·92948	·93750	·94551	·95352	·96153	·96955	·97756
5·3	·86477	·87264	·88050	·88836	·89622	·90408	·91194	·91981	·92767	·93553	·94339	·95125	·95911
5·4	·84876	·85648	·86419	·87191	·87962	·88734	·89506	·90277	·91049	·91820	·92592	·93364	·94135
5·5	·83333	·84090	·84848	·85606	·86363	·87121	·87878	·88636	·89393	·90151	·90909	·91666	·92424

	GRAINS PER HOUR CONSUMED BY THE SPERM CANDLE.												
	123	124	125	126	127	128	129	130	131	132	133	134	135
4·5	1·13888	1·14814	1·15740	1·16666	1·17592	1·18518	1·19444	1·20370	1·21296	1·22222	1·23148	1·24074	1·25000
4·6	1·11413	1·12318	1·13224	1·14130	1·15036	1·15942	1·16847	1·17753	1·18659	1·19565	1·20471	1·21376	1·22282
4·7	1·09042	1·09929	1·10815	1·11702	1·12588	1·13475	1·14361	1·15248	1·16134	1·17021	1·17907	1·18794	1·19680
4·8	1·06770	1·07638	1·08506	1·09375	1·10243	1·11111	1·11979	1·12847	1·13715	1·14583	1·15451	1·16319	1·17187
4·9	1·04591	1·05442	1·06292	1·07142	1·07993	1·08843	1·09693	1·10544	1·11394	1·12244	1·13095	1·13945	1·14795
5·0	1·02499	1·03333	1·04166	1·04999	1·05832	1·06666	1·07500	1·08333	1·09166	1·10000	1·10833	1·11666	1·12500
5·1	1·00490	1·01307	1·02124	1·02941	1·03758	1·04575	1·05392	1·06209	1·07026	1·07843	1·08660	1·09477	1·10294
5·2	·98557	·99358	1·00160	1·00961	1·01762	1·02564	1·03365	1·04166	1·04967	1·05769	1·06570	1·07371	1·08173
5·3	·96698	·97484	·98270	·99056	·99842	1·00628	1·01415	1·02201	1·02987	1·03773	1·04559	1·05345	1·06132
5·4	·94907	·95679	·96450	·97222	·97993	·98765	·99537	1·00308	1·01080	1·01851	1·02623	1·03395	1·04166
5·5	·93181	·93939	·94696	·95454	·96212	·96969	·97727	·98484	·99242	1·00000	1·00757	1·01515	1·02272

Rule.—Multiply the number standing beneath the number of grains consumed by the Candle and opposite the number of feet consumed by the Gas burner, by the illuminating power as read off from the scale of the Photometer—the product is the correct value of the Gas reduced to the standards of 120 grains per hour and 5 cubic feet per hour.

With a view to render still more easy the use of the photometer, tables have been published by Mr. Sugg, which give by inspection the corrected illuminating power of gas, varying from 10 to 15·5 candles.

These tables are arithmetically but not absolutely correct, as it is well known that the ratio of increase in the illuminating power does not correspond with the ratio of increase in the matter consumed, but they are sufficiently accurate, within the ranges given, for all practical purposes. It should, however, be borne in mind, that the nearer the quantities consumed are to the Parliamentary standards, the more accurate will be the observation.

I also here add, by the kind consent of Dr. Letheby, the table which he is in the constant habit of using to correct his photometrical observations.

This table is constructed so that, when the gas is burning at the rate of five cubic feet per hour, the observations of the hourly rate of burning of the candle and the illuminating power of the gas may be calculated into the standard value of 120 grains consumption of candle per hour. This is done, either by multiplying the first number (column 1), after the observed weight of the hourly consumption of the candle, by the observed value of the gas, and the product is the value of the gas in standard candles; or, by adding up the several numbers which correspond in the columns headed by the successive figures of the illuminating power of the gas: for example, suppose the candle burnt at the rate of 126 grains per hour, and the illuminating power of the gas, as the mean of ten observations, was 12·14. According to the first mode of calculation, the number in column 1, which is opposite 126, is 1·050; this, multiplied by 12·14 (the observed power of the gas), gives 12·747 as the illuminating power of the gas in standard candles. According to the second mode of calculating the power, the several numbers of the columns opposite 126, which correspond to the figures of the illuminating power of the gas (12·14), are as follows:—

1 . . 10·50
2 . . 2·10
1 . . 0·105
4 . . 0·042

12·747=illuminating power in standard candles.

Table for ascertaining the Standard Value of the Illuminating Power of Gas when burnt at the rate of 5 *cubic feet per hour from any experimental observation (Dr. Letheby).*

Weight of Candles consumed per Hour.	Value of Illuminating Power of the Gas in Standard Quantity (120).								
	1	2	3	4	5	6	7	8	9
Grains.									
110	0·917	1·833	2·750	3·667	4·583	5·500	6·316	7·334	8·250
111	0·925	1·850	2·775	3·700	4·625	5·550	6·475	7·400	8·325
112	0·933	1·867	2·800	3·733	4·666	5·600	6·533	7·466	8·400
113	0·942	1·883	2·825	3·767	4·708	5·650	6·592	7·534	8·475
114	0·950	1·900	2·850	3·800	4·750	5·700	6·650	7·600	8·550
115	0 958	1·917	2·875	3·833	4·791	5·750	6·707	7·666	8·625
116	0 967	1·933	2·900	3·867	4·833	5·800	6·767	7·734	8·700
117	0·975	1·950	2.925	3·900	4·875	5·850	6·825	7·800	8·775
118	0·983	1·967	2·950	3·933	4·916	5·900	6·883	7·866	8·850
119	0·992	1·983	2·975	3·967	4·958	5·950	6·942	7·934	8·925
120	1·000	2·000	3·000	4·000	5·000	6·000	7·000	8 000	9·000
121	1·008	2·017	3·025	4·033	5·042	6·050	7·057	8·066	9·075
122	1·017	2·033	3·050	4·067	5·083	6·100	7·117	8·134	9·150
123	1·025	2·050	3·075	4·100	5·125	6·150	7·175	8·200	9·225
124	1·033	2·067	3·100	4·133	5·167	6·200	7·233	8·267	9·300
125	1·042	2·083	3·125	4·167	5·208	6·250	7·292	8·333	9·375
126	1·050	2·100	3·150	4·200	5·250	6·300	7·350	8·400	9·450
127	1·058	2·117	3·175	4·233	5·292	6·350	7·408	8·467	9·525
128	1·067	2·133	3·200	4·267	5·333	6·400	7·467	8·534	9·600
129	1·075	2·150	3·225	4·300	5·375	6·450	7·525	8·600	9·675
130	1·083	2·167	3·250	4·333	5·417	6·500	7·583	8·667	9·750
131	1·092	2·183	3·275	4·367	5·458	6·550	7·642	8·733	9·825
132	1·100	2·200	3·300	4·400	5·500	6·600	7·700	8·800	9·900
133	1·108	2·217	3·325	4·433	5·542	6·650	7·758	8·866	9·975
134	1·117	2·233	3·350	4·466	5·583	6·700	7·817	8·933	10·050
135	1·125	2·250	3·375	4·500	5·625	6·750	7·875	9·000	10·125
136	1·133	2·267	3·400	4·533	5·667	6·800	7·933	9·067	10·200
137	1·142	2·283	3·425	4·567	5·708	6·850	7·992	9·133	10·275
138	1·150	2·300	3·450	4·600	5·750	6·900	8·050	9·200	10·350
139	1·158	2·317	3·475	4·633	5·792	6·950	8·108	9·267	10·425

By some engineers the illuminating power test is considered the most important of all, and it is so, most undoubtedly, in a commercial point of view. Still there are gentlemen who adhere to the bromine or chlorine tests, as the preferable method of determining the photogenic power of a gas. To those who hold this latter opinion, I would only remark, that the bromine or chlorine tests are of small value by themselves, as they do not take any account of the presence of carbonic acid or atmospheric air, both of which reduce the illuminating power to a considerable extent; and whilst the condensation would lead us naturally to expect a highly satisfactory result in the photometer, the presence of some injurious compound might produce a result at variance with what was expected. The same remarks apply to those who are so fond of quoting the specific gravity as a proof of the high illuminating power of a gas.

A photometer was used some years ago, the beam of which, instead of being placed edge uppermost, as arranged by Mr. King, was placed flatways; and being made of varnished pine, the reflection from its surface was so great as to render the observations made by it absolutely useless when compared with the results obtained by Mr. King's arrangement. I made some experiments four years ago with this arrangement of the beam, and found the light from a 15-hole Argand burner, with a 7-inch chimney, consuming, at the rate of 5 feet per hour, 23 per cent. over and above what it ought to have been according to the photometer then in ordinary use. I mention this merely to show how necessary it is, in photometrical experiments, to prevent any reflected light being thrown upon the surface of the disc, a circumstance which is scarcely possible to occur with the Evans photometer.

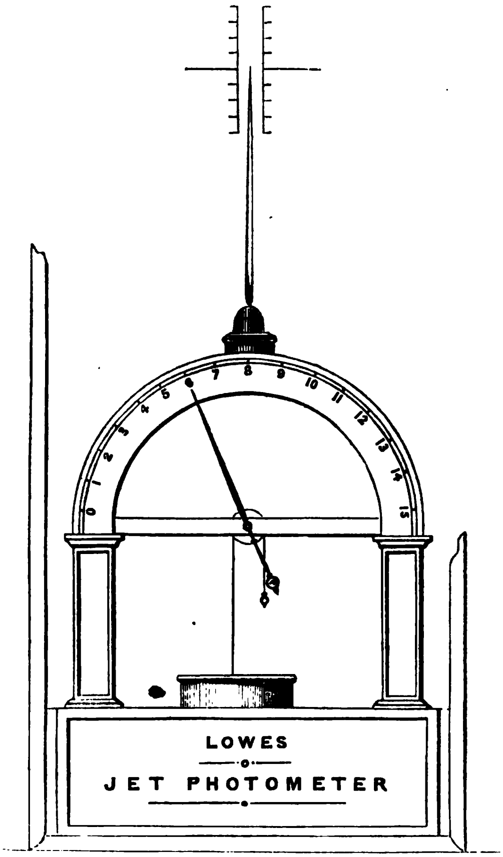
Jet photometer.

It has been observed, by Mr. George Lowe, that the length of the flame issuing under a well-regulated and constant pressure from a jet, depends in a remarkable manner upon the illuminating power of the gas. Repeated observations made by this talented engineer during the last two years have proved, beyond question, that when the jet is burning under 6-tenths of an inch pressure the flame is, as near as possible, 6 inches long—if the gas be of the illuminating power and purity required by the Metropolis Gas Act.

To enable gas engineers and others to adopt this method of testing the value of coal gas,

THE JET PHOTOMETER

has been made by Mr. Sugg, as represented in the engraving below.



It consists of a very delicate pressure gauge, similar to those made by Mr. King of Liverpool. The index is so large that one-hundredth of an inch can be easily read off, one-tenth of an inch variation in the level of the water being equivalent to one inch on the scale. The needle is suspended on finely polished cone pivots, so that the least increase or decrease in the pressure on the surface of the water is immediately communicated to the pointer, and the alteration in the level shown on the index, ten times its real magnitude. The gas ways to the jet are made about two thousand five hundred times larger in sectional area than the jet itself, in order to insure the greatest possible accuracy in the performance of the instrument. The whole of the apparatus is enclosed in a wooden box, with a glass front, so that the flame may be perfectly steady, and free from the flickering which would result if it were exposed to the open air. Upon the glass front a scale of inches is engraved, divided into tenths, and a similar scale on ivory is attached to the back of the box, the zero points on both scales being exactly level with the top of the jet. Every engineer must determine for himself, by reading both scales, the length of the flame which the gas he is manufacturing will produce, under any pressure he may think proper. The length, of course, will vary with the specific gravity of the gas, and the pressure under which it is consumed.

Self-registering photometer.

It is very much to be desired that a self-registering photometer should be constructed, on a principle similar to the apparatus employed by Mr. J. Glaisher, of the Greenwich Observatory, for recording the variations of the barometer and thermometer. Mr. Glaisher causes a ray of light from a gas-burner to impinge upon the surface of a sheet of iodized paper (similar to that used in the calotype process), attached to a drum which revolves once in twenty-four hours. A mark is produced upon the paper corresponding with the height of the mercury in the tube of the barometer or thermometer. A somewhat similar apparatus might be used to record the length of the gas flame in the jet photometer. If the image of this flame were recorded upon a register paper, as indicated above, its apex would trace a certain line, which being referred to a standard line, as in the well-known registering pressure gauge, the illuminating power of the gas for every period of the twenty-four hours would be recorded, and an infinity of labour saved to gas engineers and others employed in making observations by the Bunsen photometer.

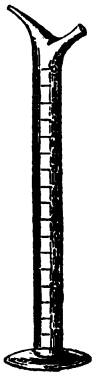
The standard line in this illuminating power indicator would be ascertained by carefully determining the exact length of a jet of gas, of the standard illuminating power, burning under a given pressure.

TAR AND AMMONIACAL LIQUOR.

Tar.

Ammoniacal liquor.

The quantity of tar and ammoniacal liquor in the coal will be ascertained by running off those compounds from the ⅜ brass cocks in the condenser. Both vary much in their character, according to the quality of the coal and the temperature at which it has been distilled. If the retort is worked at a high heat, the tar is neither so large in quantity nor so good in quality as when a low heat is employed. The liquor from bituminous coals contains generally a great deal more ammonia than that from the Cannel or Boghead seams, but the tar is not nearly so rich in hydro-carbon compounds, and is specifically heavier than that obtained from those sources. The strength of the ammoniacal liquor is generally determined in the following manner:—the value of the liquor depends upon the quantity of commercial salt it is capable of producing, and in order to ascertain this, sulphuric acid is mixed with a given quantity of liquor till the solution is neutral, which is known by its not reddening blue litmus paper. The test acid employed is called "ten per cent. acid," and is prepared in the following manner:—one pound of strong sulphuric acid (specific gravity, 1845) is mixed with water till the solution measures exactly one gallon, the specific gravity of which will be found to be 1068·2. If, now, a glass vessel, divided into sixteen exactly equal parts and graduated accordingly, be filled with this test solution, each division will represent one-sixteenth of a pound, or one ounce of sulphuric acid. Such an instrument as this is called an alkalimeter, and is represented in the adjoining figure. Fill the alkalimeter to the line marked zero with ammoniacal liquor, and pour it into a dish; wash out with clean water, and pour the washings into the dish also. Now fill with the test acid to zero, and pour into the dish, carefully stirring up the mixture at the



same time with a glass rod. Note the point of saturation, which will be ascertained by the mixture slightly reddening litmus paper. Read off the number of ounces of test acid poured off from the alkalimeter—say six ounces, or six divisions rather—and this will represent the strength of the liquor, which will be called "six-ounce liquor" accordingly.

Test acid. It is necessary to test this acid solution occasionally, not only by its specific gravity—which ought to be 1068·2—but also by saturation with carbonate of soda. The carbonate of soda of commerce is taken and thoroughly dried at a red heat so as to drive off all the water of crystallization; if the test acid is of the proper strength, 1,000 grains of it ought to saturate 110 grains of this dry salt.

Litmus paper is used to ascertain when the solution is rendered neutral: if acid, the blue colour of the litmus will be changed to red; if alkaline, the litmus will retain its colour; if neutral, the litmus will be changed to a purple colour.

QUALITY OF COKE.

Ash in coke. The quantity of ash in the coke is ascertained in the following manner:—the coke to be examined is first carefully weighed, and then transferred to the furnace, shown in the adjoining figure. This is a small fire-clay furnace, provided with various stoppers and sight holes, and is used principally for the assaying of metals. A strong gas jet, passing through the grating in the bottom is made to come in contact with the coke, which, being thus easily kindled, and a good draught maintained through the chimney, is left to burn itself out. The ash is then carefully collected and weighed, and being compared with the quantity of coke originally put into the furnace, the percentage of ash is determined.* If it is desired to determine the nature of this ash, it can be easily

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* If 100 grains of finely-powdered coke be consumed in a platinum capsule over a Bunsen burner, the number of grains left will be the percentage of ash in the coke.

done by treating it at the blow-pipe with a weak solution of nitrate of cobalt. If magnesia is present, it will render the flame a pale flesh colour; if alumina, it will be blue; if alumina and oxide of iron, a dirty green; and if lime, a greyish black.

Sulphur in coke.

The next process is to determine the quantity of sulphur existing in the coal or coke. The following method was first suggested, I believe, by Mr. Lewis Thompson, a gentleman to whom the chemistry of gas lighting is more indebted than to any other. A mixture is first prepared consisting of 100 grains of finely pounded coke or coal, and about 30 grains of pure carbonate of soda, also reduced to a fine powder. This is put into a small iron ladle and exposed to the heat of a brisk fire. The carbonaceous particles of the coal or coke are soon burnt off, and the sulphur combines with the metallic portion of the soda, forming sulphuret of sodium. This is now to be sprinkled with powdered nitrate of potash as long as deflagration continues, and then allowed to remain at a bright red heat for some minutes; by this means the sulphuret of sodium is rapidly converted into the sulphate of soda. The ladle is now allowed to cool, when the salt is to be dissolved by means of boiling water. This solution must now be filtered in the usual way, and then saturated with nitric acid. A strong solution of nitrate of baryta is next to be added, when a precipitate of sulphate of baryta is thrown down. This must be collected on a filter paper, previously weighed, well washed with boiling distilled water, dried and weighed in the usual way. For every 117 grains of salt so obtained there would be 16 grains of pure sulphur; and knowing these proportions, the quantity in 100 grains of coal or coke can be at once calculated.

To find the sulphur passed off in the volatile matter of the coal, it is only necessary to treat the coke obtained from 100 grains of coal in precisely the same manner as that indicated above. The quantity so obtained is to be deducted from the previously ascertained quantity in 100 grains of coal, and the remainder will represent the sulphur volatilised during the process of distillation.

HEATING POWER OF GAS.

In consequence of the very general use of gas stoves for culinary and warming purposes, it may be as well to make a few remarks on the heating power of carburetted hydrogen gas, and the method employed to ascertain the exact amount given off during combustion. Some experiments were made in 1852 and 1853 by Mr. Lewis Thompson with this object. The apparatus employed by him was similar to the condenser previously referred to when describing the process adopted for determining the quantity of bi-sulphide of carbon in coal gas. A burner, consuming at the rate of 10 feet per hour, was placed under this condenser, so that the heated air arising from the gas in combustion was allowed to travel slowly through the worm, and thus be deprived of its surplus heat. The following table exhibits the results of observations carried on in this manner for fourteen months upon the gas supplied by three of the Metropolitan Gas Companies, from which it appears that 25 feet of gas, from Newcastle coal, will evaporate one gallon of water.

Table of observations of the calorific power of gas when consumed in a burner at the rate of 10 *cubic feet per hour.*

Heating power of gas.

	Grains of water evaporated by one cubic foot of the Gas of the		
	Great Central Company.	City of London Company.	Chartered Company.
1852.			
May	2,410	2,786	
June	2,667	2,823	2,858
July	2,795	2,870	2,886
August	2,608	2,792	2,810
September	2,676	2,820	2,614
October	2,634	2,745	2,702
November	2,660	2,805	2,822
December	2,625	2,829	2,830
1853.			
January	2,704	2,957	2,964
February	2,892	2,910	2,901
March	2,839	2,900	2,871
April	2,514	2,896	2,888
May	2,654	2,865	2,749
June	2,726	2,856	2,733
Average	2,671	2,846	2,817

From this table it appears that 30 feet, or 1 lb. in weight, of gas applied, as above explained, will evaporate 12 lbs. of water.

In a table, showing the heating power of various kinds of fuel, derived from Mr. Wicksteed's experiments, and published in the *Artizan Club Treatise on the Steam Engine*, the water evaporated by 1 lb. of the best small Newcastle coal is stated to be 8·524 lbs., and by 1 lb. of gas coke 7·908 lbs.; but from a number of experiments made by myself in 1858 with the same object, I found that 7·36 lbs. of water were evaporated by 1 lb. of coke, and 6·39 lbs. by 1 lb. of Newcastle coal. These experiments were continued for ten days, and were made with an ordinary 6-horse Cornish boiler, set in the usual way. It thus appears that 1 lb. of Newcastle coal gas will evaporate, when properly consumed, nearly twice as much water as an equal weight of either coke or coal, consumed in the manner explained above.

GAS BURNERS.

Quantity and intensity of light.

In referring to the various kinds of burners used for coal gas, it must be remarked that the photogenic power of any luminiferous agent depends upon two conditions—*quantity* and *intensity*. By *quantity*, I mean that the carbonaceous particles of the flame are numerous; by *intensity*, that they are highly heated. Now the perfection of gas illumination consists in providing a burner, so constructed that these two conditions just balance each other. This subject appears to be very little understood by many burner-makers. In fact, in some experiments made recently on 15-hole Argand burners, obtained from different establishments, I have found the illuminating power of 5 feet of gas to vary as much as 50 per cent., simply through the above conditions not being properly attended to. The oxyhydrogen lime-light is an excellent example of *intensity*, the number of particles of carbon being very small, but the temperature to which they are heated very high. The *quantity* of light from a solid wick oil lamp is great, but the *intensity* is small. So that there may be great *intensity* where the *quantity* is small, or great *quantity* where *intensity* is small. If a straight wire be passed through the flame of a common candle, there will be no increase of illuminating power, because the flame of the candle already contains more solid constituents than can be satisfactorily heated by the hydrogen of the tallow; whereas with Newcastle gas, burning from an ordinary batwing or fishtail burner, exactly the reverse is the case, because the hydrogen is in excess, and the solid matter deficient. Now if the colour of the flame from a well-constructed Argand burner be compared with that from a fishtail or batwing, it will be observed that the former is brown and the latter blue, which clearly shows that the quantity of light exceeds the intensity in the Argand, whereas with the batwing or fishtail the intensity exceeds the quantity.

If the light produced from 5 feet of gas consumed in a 15-hole Argand burner, be equal to 13 candles, the light from a similar quantity of gas, consumed in a batwing or fishtail burner, will not exceed 9 candles; and the reason the batwing burner gives so bad a result, when compared with the Argand, is because there is too great a contact with the atmospheric oxygen in the lower part of the flame of the batwing; and this is easily proved by causing two flames, from batwing or fishtail burners, to impinge upon one another, and thus reduce the surface in contact with the atmosphere by nearly one-half; for, by such an arrangement as this, 5 feet of gas, consumed in a double batwing burner, gives the same amount of light as 5 feet consumed in a 15-hole Argand of the best construction. And, guided by these observations, I think it follows that every burner has a certain fixed amount of gas which it will consume with the greatest photogenic advantage, and that when the gas is issuing from the burner at so low a pressure that the flame is just upon the point of smoking, the maximum effect for the quantity of gas consumed in that particular burner is obtained, because, in this case, the quantity and intensity of the light are so advantageously balanced, that the greatest illuminating power is the result. And, by the same reasoning, I think it also follows, that the burner best suited for the combustion of coal gas, is one in which the openings are large, so as to prevent, as much as possible, too great contact with the air in the lower part of the flame—an evil to be carefully avoided, for every one knows that an Argand burner, consuming 5 feet of gas, does not give so much light with a 9-inch chimney as with a 7-inch, because, with the former, there is a much larger supply of air than with the latter.

Discharge of gas through small orifices.

The laws which govern the discharge of gas through small orifices are exceedingly simple, and depend upon the specific gravity of the gas, and the pressure under which it is discharged.

The quantity of gas of the specific gravity of ·413 discharged through a ⅜ jet, under the following pressures, was as the result stated below :—

Pressure.	Gas consumed per Hour.	Pressure.	Gas consumed per Hour.
15 tenths.	31·0 feet.	3 tenths.	13·5 feet.
10 „	26·0 „	2 „	11·8 „
5 „	17·5 „	1 „	7·8 „
4 „	16·3 „		

Now, taking the standard quantity as 31 feet discharged, under 15-tenths pressure, and calculating the quantity discharged under any other pressure as the square root of that pressure, we get the following results :—

Pressure.	Gas consumed per Hour by Experiment.	Gas consumed per Hour by Calculation.
15 tenths.	31·0 feet.	. .
10 „	26·0 „	25·3 feet.
5 „	17·5 „	17·8 „
4 „	16·3 „	16·02 „
3 „	13·5 „	13·8 „
2 „	11·8 „	11·4 „
1 „	7·8 „	8·0 „

Hence, it appears, that the number of cubic feet of gas discharged through a small orifice,* under various pressures, is as the square root of those pressures. Similarly, it may be shown, that the quantity of gas discharged through a given orifice, under the same pressures, is as the square root of its specific gravity. This is established pretty clearly by filling an ordinary 10-feet gasholder with gases of different densities, and allowing them to blow off under similar pressures. If the time is carefully noted the truth of the above statement can be easily verified. The following results have been obtained from an experiment made in this manner :—

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* It will be seen further on, in the tables of the quantities of gas discharged by ordinary gas burners, that there is a remarkable exception to this rule in the case of batwing and fishtail burners, working below six or seven-tenths pressure.

	Quantity Discharged.	Specific Gravity.	Time, by Observation.	Time, by Calculation.
Air . . .	10 feet.	1·000	195 seconds.	..
Cannel Gas . .	10 „	·580	145 „	148 seconds.
Common Gas . .	10 „	·419	120 „	126 „

The barometer at the time was 30·2 inches, and the temperature of the air 50°. The figures in the second column were, of course, corrected to the standard temperature of 60°, and barometric pressure of 30 inches.

In order to make this subject more clear, and to show that the remarks I have made are founded upon the results of actual experiment, I subjoin the following tables, which I think prove satisfactorily the correctness of the observations I have made upon this part of the subject.

The following experiments were made, in 1860, with common batwing burners, Nos. 3, 4, 5, and 6. The gas, at the time tested with a 15-hole Argand burner, 7-inch chimney, consuming 5 feet per hour, gave a light equal to 14 standard candles.

Pressure.	Burner.	Quantity consumed.	Illuminating power.	Reduced to 5 feet per hour.	Value of 1 foot of Gas in Standard Candles.
25 tenths.	No. 3 Batwing.	5·5 feet.	6 candles.	5·45	1·09
20 „	„	5·0 „	6 „	6·0	1·2
15 „	„	4·0 „	5·2 „	6·5	1·3
10 „	„	3·2 „	5·1 „	8·0	1·6
5 „	„	2·0 „	4·2 „	10·5	2·1
25 tenths.	No. 4 Batwing.	7·6 „	9·0 „	5·9	1·18
20 „	„	6·6 „	9·0 „	6·8	1·36
15 „	„	5·5 „	8·0 „	7·2	1·45
10 „	„	4·1 „	6·75 „	8·2	1·64
5 „	„	2·8 „	5·0 „	8·9	1·78
25 tenths.	No. 5 Batwing.	7·9 „	10·5 „	6·6	1·32
20 „	„	6·7 „	10·5 „	7·8	1·56
15 „	„	5·4 „	9·6 „	8·8	1·75
10 „	„	4·5 „	8·5 „	9·4	1·88
5 „	„	2·6 „	6·0 „	11·5	2·30
25 tenths.	No. 6 Batwing.	12·5 „	9·75 „	3·90	0.78
20 „	„	11·0 „	13·5 „	6·13	1·22
15 „	„	9·5 „	12·5 „	6·57	1·31
10 „	„	7·8 „	11·0 „	7·05	1·41
5 „	„	5·0 „	9·0 „	9·00	1·80
2½ „	„	3·0 „	5·5 „	9·17	1·83

The slits in the burners, Nos. 3, 4 and 5, were now slightly enlarged, by passing a saw through them, when the following results were obtained:—

Pressure.	Burner with enlarged Slit.	Quantity Consumed.	Illuminating Power.	Reduced to 5 feet per Hour.	Value of 1 foot of Gas in Standard Candles.
25 tenths.	No. 3 Batwing.	9·4 feet.	12·0 candles.	6·38	1·27
20 „	„	7·3 „	12·0 „	8·19	1·64
15 „	„	6·5 „	11·0 „	8·46	1·70
10 „	„	5·0 „	9·0 „	9·00	1·80
5 „	„	3·6 „	6·5 „	9·03	1·80
25 tenths.	No. 4 Batwing.	9·0 feet.	10·5 „	5·83	1·16
20 „	„	7·8 „	10·5 „	6·73	1·34
15 „	„	6·5 „	10·0 „	7·69	1·54
10 „	„	5·0 „	9·5 „	9·50	1·90
5 „	„	3·0 „	7·0 „	11·66	2·33
25 tenths.	No. 5 Batwing.	9·5 feet.	12·5 „	6·58	1·31
20 „	„	8·1 „	12·5 „	7·71	1·54
15 „	„	6·9 „	11·5 „	8·33	1·66
10 „	„	6·0 „	10·0 „	8·33	1·66
5 „	„	3·6 „	7·0 „	9·72	1·94

From an inspection of these tables, it appears that in each case when the gas was issuing with the lowest pressure, that is, when there was the least atmospheric contact with the lower part of the flame, the photogenic power was greatest; and when the gas was issuing under the heaviest pressure, and there was consequently the greatest atmospheric contact, the photogenic power was least.* This appears very conclusively in the sixth column, where, opposite five-tenths pressure in each table, it will be seen that the value of one foot of gas in standard candles far exceeds that of the same quantity of gas consumed under higher pressure.

It has been already stated that the discharge of gas through small orifices is as the square root of the pressure, but that this does not hold good with fishtail and batwing burners below six or seven-tenths pressure; for, in this case, the discharge seems to be almost directly as the pressure. In order to substantiate this remark, I subjoin the following tables of experiments made with batwing burners, consuming both Cannel and common gas, and also with a very large fishtail burner, consuming common gas only. The batwing burner employed, and which I have called No. 1, is made to consume 5 feet of Cannel gas; and it will be seen that when that quantity is consumed per hour, the greatest value for one foot of gas in standard candles is obtained; and it will also be observed that such a burner is not at all adapted for the combustion of common gas. The fishtail burner is of very large size, and might well be compared with the double batwing burner, which gives a result equal to the Argand. In constructing the following tables, a pressure-gauge was employed on which the two-hundredth of an inch is easily recorded, and the most sensitive governors were used. The gas was tested, before commencing the experiments, with a 15-hole Argand burner, and was found to equal 14 standard candles. A jet of Cannel gas was now substituted for the candle, and, after each burner had been experimented upon, this jet was compared with the standard Argand, as at the commencement. Some small variations occurred in the illuminating power of the gas, which were corrected by adjusting the jet so that the Argand burner always gave a light fourteen times larger than the jet. The results obtained, therefore, show the comparative value of the various burners examined.

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* Since the above was written, a pamphlet has been published by MM. Audouin and Bérard, which fully confirms the above remark.

Burner.	Pressure.	Illuminating Power—Standard Candles.	Value of 1 foot of Gas in Standard Candles.	Gas Consumed.	
				Actual.	Calculated.
Newcastle Gas.					
Large Fishtail.	10 tenths.	15·64	1·70	9·2 feet.	..
	9 „	15·16	1·78	8·5 „	8·73 feet.
	8 „	14·58	1·82	8·0 „	8·23 „
	7 „	16·33	2·15	7·6 „	7·70 „
	6 „	18·66	2·66	7·0 „	7·13 „
	5 „	15·98	2·57	6·2 „	6·50 „
	4 „	14·00	2·54	5·5 „	5·83 „
	3 „	10·50	2·33	4·5 „	5·03 „
	2 „	7·87	2·24	3·5 „	4·10 „
	1 „	4·66	2·02	2·3 „	2·91 „
Large Batwing, No. 1.	10 tenths.	9·5	1·58	6·0 feet.	..
	9 „	8·7	1·58	5·5 „	5·69 feet.
	8 „	8·0	1·54	5·2 „	5·36 „
	7 „	6·9	1·53	4·5 „	5·01 „
	6 „	6·1	1·49	4·1 „	4·64 „
	5 „	5·3	1·44	3·7 „	4·24 „
	4 „	4·5	1·45	3·1 „	3·79 „
	3 „	3·6	1·44	2·5 „	3·28 „
	2 „	2·4	1·33	1·8 „	2·68 „
	1 „	1·0	1·00	1·0 „	1·89 „

Burner.	Pressure.	Illuminating Power—Standard Candles.	Value of 1 foot of Gas in Standard Candles.	Gas Consumed.	
				Actual.	Calculated.
Newcastle Gas.					
Large Batwing, No. 2.	10 tenths.	14·0	1·70	8·2 feet.	..
	9 ,,	13·2	1·71	7·7 ,,	7·77 feet.
	8 ,,	12·3	1·73	7·1 ,,	7·33 ,,
	7 ,,	11·0	1·77	6·2 ,,	6·85 ,,
	6 ,,	9·8	1·78	5·5 ,,	6·35 ,,
	5 ,,	8·75	1·86	4·7 ,,	5·79 ,,
	4 ,,	7·00	1·79	3·9 ,,	5·18 ,,
	3 ,,	5·5	1·77	3·1 ,,	4·49 ,,
	2 ,,	3·7	1·68	2·2 ,,	3·66 ,,
	1 ,,	1·8	1·50	1·2 ,,	2·59 ,,
Cannel Gas.					
Large Batwing, No. 1.	10 tenths.	29·03	5·58	5·2 feet.	..
	9 ,,	25·20	5·04	5·0 ,,	4·93 feet.
	8 ,,	21·00	4·66	4·5 ,,	4·74 ,,
	7 ,,	18·43	4·39	4·2 ,,	4·34 ,,
	6 ,,	15·50	4·19	3·7 ,,	4·02 ,,
	5 ,,	13·12	4·10	3·2 ,,	3·67 ,,
	4 ,,	10·50	4·03	2·6 ,,	3·28 ,,
	3 ,,	8·00	4·00	2·0 ,,	2·74 ,,
	2 ,,	4·30	3·30	1·3 ,,	2·32 ,,
	1 ,,	2·00	2·66	0·76 ,,	1·64 ,,

The large slot Argand burner used in the following table is constructed to consume 7 feet per hour with a 7-inch chimney, and the 15-hole Argand is the ordinary Parliamentary burner, as first made in 1859.

Burner (Newcastle Gas).	Pressure.	Illuminating Power.	Value of 1 foot of Gas in Standard Candles.	Gas Consumed.	
				Actual.	Calculated.
Large Slot Argand, 7-in. chimney.	3·6 tenths.	22·00	3·14	7·0 feet.	..
	3·0 ,,	18·50	2·93	6·3 ,,	6·39 feet.
	2·5 ,,	14·25	2·64	5·4 ,,	5·83 ,,
	2·0 ,,	12·50	2·55	4·9 ,,	5·21 ,,
	1·5 ,,	9·00	2·14	4·2 ,,	4·51 ,,
	1·0 ,,	5·50	1·57	3·5 ,,	3·69 ,,
15-Hole Argand, 7-in. chimney.	0·45 tenths.	14·0	2·80	5·0 feet.	..
	0·35 ,,	10·7	2·54	4·2 ,,	4·40 feet.
	0·20 ,,	6·8	2·06	3·3 ,,	3·33 ,,
	0·09 ,,	2·6	1·17	2·2 ,,	2·24 ,,
	0·06 ,,	1·0	0·55	1·8 ,,	1·82 ,,

In comparing the results thus tabulated, it is very interesting to note the difference in the value of 1 foot of gas in standard candles when consumed in the largest sized batwing and fishtail burners. With the former, it is 1·88, with the latter, 2·66 candles. The fishtail burner, in fact, when the holes are of large diameter, is nearly equal to the double batwing, and very little behind the best results obtained from the Argand.

The following table exhibits the best results obtained from each kind of burner.

Burner (Newcastle Gas).	Pressure.	Illuminating Power.	Value of 1 foot of Gas in Standard Candles.	Gas Consumed.	
				Actual.	Calculated.
Large Argand Slot	3·6 tenths	22·00 candles.	3·14	7·0 feet.	..
15-Hole Argand ..	0·45 „	14·00 „	2·80	5·0 „	..
Double Batwing ..	3·7 „	13·75 „	2·75	5·0 „	..
Large Fishtail	6· „	18·66 „	2·66	7·0 „	7·13
Large Batwing, No. 2	5· „	8·75 „	1·86	4·7 „	5·79
Ditto No. 1	10· „	9·50 „	1·58	6·0 „	..

It is also worthy of remark that the 15-hole Argand requires less pressure to produce the maximum illuminating power than any other burner in this table.

The following table shows the comparative value of 5 feet of gas consumed by several batwing and fishtail burners, and I have also added the double batwing burner, to show the great difference in value of 5 feet of gas consumed in the combined flame, in one distinct flame, and in two separate flames—the results being respectively 13·75, 7·60, and 8·40 standard candles.

Burner (Newcastle Gas).	Pressure.	Illuminating Power.	Value of 1 foot of Gas in Standard Candles.	Gas Consumed.
Batwing Burners—				
No. 8	5·5 tenths.	9·4	1·88	5 feet.
No. 7	4·6 ,,	9·0	1·80	5 ,,
No. 6	10·5 ,,	8·0	1·60	5 ,,
No. 5	4·6 ,,	8·6	1·72	5 ,,
No. 4	9·7 ,,	5·7	1·14	5 ,,
No. 3	16·0 ,,	3·5	0·70	5 ,,
Fishtail Burners—				
No. 8	3·5 tenths.	12·1	2·42	5 feet.
No. 6	6·6 ,,	9·3	1·86	5 ,,
No. 5	8·8 ,,	6·3	1·26	5 ,,
No. 4	13·9 ,,	5·1	1·02	5 ,,
No. 3	18·0 ,,	2·1	0·50	4·2 ,,
Double Batwing.				
2. No. 5—				
Both burning	3·7 tenths.	13·75	2·75	5 feet.
One shut off......	9·0 ,,	7·60	1·52	5 ,,
Ditto	3·5 ,,	4·20	1·68	2·5 ,,

The following table is added here to show the comparative value of burners when consuming Cannel gas, from which it will be seen that burners of the Argand form, though the best for Newcastle gas, are not so favourable for the combustion of gases of high illuminating power.

Burner (Cannel Gas).	Gas Consumed.	Illuminating Power.	Reduced to 5 feet per Hour.	Value of 1 foot of Gas in Standard Candles.
No. 8 Batwing . .	5·0 feet.	31·0 candles.	31·0 candles.	6·20
30-hole Argand, 6-inch chimney . . .	4·5 ,,	26·5 ,,	29·4 ,,	5·88
No. 4 Fishtail . .	2·5 ,,	13·0 ,,	26·0 ,,	5·20
30-hole Argand, 7-inch chimney . . .	4·1 ,,	20·0 ,,	24·4 ,,	4·89
Leslie Burner, 3½-inch chimney . . .	3·1 ,,	15·0 ,,	24·2 ,,	4·83
Lava Batwing . .	2·8 ,,	13·5 ,,	24·1 ,,	4·82
15-hole Argand, 6-inch chimney . . .	2·8 ,,	11·5 ,,	20·5 ,,	4·10
No. 2 Batwing Burner .	3·0 ,,	12·0 ,,	20·0 ,,	4·00
15-hole Argand, 7-inch chimney . . .	3·3 ,,	13·0 ,,	19·7 ,,	3·94
No. 2 Fishtail . .	2·5 ,,	8·5 ,,	17·0 ,,	3·40

It is curious to remark that, from this table, it appears that the large batwing produces the best result, when consuming Cannel gas, and is 57 per cent. superior to the 15-hole Argand Parliamentary burner; but when consuming common gas, the converse of this is the fact—the standard Argand burner will, from an inspection of the previous tables, be found to produce a light, from each cubic foot of gas, 50 per cent. superior to the large batwing. The above burners are not chosen for any particular advantages they may possess, but were merely some I happened to have by me.

By a careful consideration of all the conditions to be fulfilled, and a most elaborate series of experiments, Mr. Sugg has succeeded in constructing various kinds of Argand and other burners, which are, perhaps, superior to any others. The 15-hole Argand, with a lava top, of his manufacture, was first used by myself in photometrical observations, in February, 1859; and a similar burner was exhibited by Mr. George Lowe to the Committee of the House of Lords who sat on the Metropolis Gas Act, in 1860. This is the kind of burner now supplied by Mr. Sugg, with his photometers.

ANALYSES OF COALS.

The following analyses of Cannel and bituminous coals are by Mr. Lewis Thompson, and were published in the 2nd and 3rd volumes of the *Journal of Gas Lighting.* They are reproduced here by the kind permission of the Editor of that paper.

It must be understood that in each case dry coals were operated upon, and the results of the analyses are stated in the following order:—The first column states the name of the coal; the second, its general character; the third, the percentage of volatile matter given off during distillation; the fourth, the percentage of coke left in the retort; the fifth, the percentage of ash left after burning the coal in the open air; the sixth, the nature of this ash; the seventh, eighth, and ninth, the percentage of sulphur in the coal, coke, and volatile matter respectively; and the tenth column represents the percentage of ash left after burning the coke in the open air.

ANALYSES OF CANNEL COALS.

Name of Cannel.	General Character.	Volatile Matter.	Coke.	Ash.	Nature of Ash.	Sulphur in			Ash in Coke, per Cent.
						Coal.	Coke.	Volatile Matter.	
Arniston	Resembling lignite, and containing crystals of carbonate of lime, with impressions of leaves and deposits of iron pyrites. Compact. Principal fracture, slaty; cross fracture, irregular. Streak, dull brownish black. Thrown on the fire, it decrepitates, but does not fly. Colour of ash, a dirty grey; with nitrate of cobalt, greenish black. Specific gravity of coal, 1·1967.	45·5	54·5	4·18	Silicate of lime, alumina, and oxide of iron.	1·70	·95	·75	7·66
Boghead	Brown, compact, and massive, containing a few impressions of sigillaria. Principal fracture, slaty, conchoidal; cross fracture, irregular. Streak, yellow. Thrown on the fire, decrepitates slightly, does not fuse, but splits. Colour of ash, white; with nitrate of cobalt, blue. Specific gravity, 1·221.	68·4	31·6	22·8	Silicate of alumina.	·53	·08	·45	70·25
Capeldrae ..	Massive, dull black, impressions of sigillaria, with deposits of carbonate of lime and pyrites. Principal fracture, conchoidal and slaty; cross fracture, distinctly conchoidal. Streak, yellowish brown. Thrown on the fire, decrepitates, splits, and flies, but does not fuse. Ash, white; with nitrate of cobalt, blue. Specific gravity, 1·2275.	54·5	45·5	10·5	Silicate of alumina.	·65	·20	·45	23·07
Kirkness	Massive and foliated, free from foreign matters. Dull brown. Principal fracture, slaty; cross fracture, conchoidal. Streak, brown. Scarcely decrepitates on the fire. Colour of ash, whitish grey; with nitrate of cobalt, dull dark blue. Specific gravity, 1·2080.	60·	40·	13·5	Silicate of alumina, lime, and oxide of iron.	1·40	·58	·82	33·7

ANALYSES OF CANNEL COALS—(*continued*).

Name of Cannel.	General Character.	Volatile Matter.	Coke.	Ash.	Nature of Ash.	SULPHUR IN			Ash in Coke, per Cent.
						Coal.	Coke.	Volatile Matter.	
KNIGHTSWOOD .	Compact, dull black, massive, with deposits of carbonate of lime and iron pyrites. Principal fracture, slaty, conchoidal; cross fracture, conchoidal. Streak, shining black. Thrown on the fire, decrepitates and flies, but does not fuse. Colour of ash, pale umber; with nitrate of cobalt, dull black.	48·5	51·5	2·4	Oxide of iron and silicate of lime, with alumina.	1·10	·61	·49	4·66
LESMAHAGO ..	Massive, dull black. Principal fracture, slaty, conchoidal; cross fracture, conchoidal and angular. Streak, black and somewhat shining. Thrown on the fire, decrepitates slightly, does not split or fuse. Colour of ash, white; with nitrate of cobalt, dirty blue. Specific gravity, 1·2220.	49·6	50·4	9·1	Silicate of alumina and oxide of iron.	2·23	1·14	1·09	18·05
LOCHGELLY ..	Colour, dull black and slaty. Fracture, inclining to slaty; cross fracture, irregular conchoidal. Streak, shining black. On the fire, decrepitates and flies. Ash, white; with nitrate of cobalt, blue. Specific gravity, 1·320.	33·5	66·5	13·1	Silicate of alumina.	·75	·25	·50	29·7
OLD WEMYSS .	Compact, dull brownish black; free from foreign matters. Principal fracture, slaty; cross fracture, angular, inclining to conchoidal. Streak, dull brownish black. Thrown on the fire, decrepitates and splits, but does not fly. Colour of ash, dull white; with nitrate of cobalt, olive green. Specific gravity, 1·3256.	52·5	47·5	15·1	Oxide of iron and silicate of alumina.	1·30	·60	·70	31·78

ANALYSES OF CANNEL COALS—(*continued*).

Name of Cannel.	General Character.	Volatile Matter.	Coke.	Ash.	Nature of Ash.	Sulphur in			Ash in Coke, per Cent.
						Coal.	Coke.	Volatile Matter.	
Wigan	Compact, black and shining. Principal fracture, conchoidal; cross fracture, conchoidal and cubical. Streak, shining black and waxy. Thrown on the fire, decrepitates, flies, and slightly fuses. Colour of ash, yellowish brown, inclining to red; with nitrate of cobalt, olive black. Specific gravity, 1·271.	37·	63·	3.	Oxide of iron and silicate of alumina.	1.25	·60	·65	4·76
Ramsay's Newcastle.	Compact and massive, slightly tinged with oxide of iron. Black and shining. Principal fracture, highly conchoidal and resinoid; cross fracture, conchoidal and cubical. Thrown on the fire, decrepitates and flies to pieces, inclined to fuse. Colour of ash, reddish brown; with nitrate of cobalt, dull black. Specific gravity, 1·290.	36·8	63·2	6·6	Oxide of iron and silicate of lime, with alumina.	1·75	·94	·81	10·44
Band of Cannel in *Leverson's Wallsend Coal.*	This is a dull black band, which runs through the mass of the coal. Fracture, slaty, conchoidal; cross fracture, cubical and conchoidal. Streak, black and shining. On the fire, splits, but does not fly or fuse. Ash, dull white, with shade of pink; with nitrate of cobalt, dull black. Specific gravity, 1·320.	30·8	69·2	9·35	Oxide of iron and silicate of lime, with alumina.	1·00	·50	·50	13·67
Band of Cannel in *Pelton Main Coal.*	Colour, dull black, with a shade of brown. Structure, compact and uniform. Fracture, conchoidal and slaty; cross fracture, irregular, conchoidal, with deposits of iron pyrites. Streak, black and shining. On the fire, splits, but does not fly; agglutinates and intumesces slightly Ash, dirty white, with shade of pink; by nitrate of cobalt, black. Specific gravity, 1·320.	31·5	68·5	9·4	Oxide of iron and silicate of lime, with alumina.	·95	·49	·46	13·7

ANALYSES OF CANNEL COALS—(*continued*).

Name of Cannel.	General Character.	Volatile Matter.	Coke.	Ash.	Sulphur in			Ash in Coke, per Cent.
					Coal.	Coke.	Volatile Matter.	
Band of Cannel in *Washington Coal.*	This resembles the Pelton and Leverson's bands. Colour, dull brownish black. Fracture, irregular, conchoidal; cross fracture, cubical and conchoidal. Streak, shining black. On the fire, splits and fuses slightly. Ash, dirty white, with shade of pink. Specific gravity, 1·326.	27·4	72·6	9·37	1·10	·56	·54	12·9
Staffordshire	Compact and uniform. Fracture, in all directions conchoidal, with deposits of carbonate of lime. Streak, shining black. On the fire, decrepitates and flies, but does not fuse. Ash, dirty white. Specific gravity, 1·220.	50·	50·	2·9	1·30	·52	·78	5·8
New Brunswick ..	Jet black, and pitchy looking. Fracture, highly conchoidal and resinoid in all directions. Streak, dull and pitchy. On the fire, cracks and splits, then fuses and boils up with strong intumescence. Largely soluble in naphtha, oil of turpentine, and bisulphuret of carbon. Specific gravity, 1·098. The coke is light and friable, like that from pitch.	66·3	33·7	·6	·07	None.	·07	1·78

ANALYSES OF BITUMINOUS COALS.

Name of Coal.	General Character.	Volatile Matter.	Coke.	Ash.	SULPHUR IN			Ash in Coke, per Cent.
					Coal.	Coke.	Volatile Matter.	
CHESHIRE—								
Harecastle........	Structure laminated, with numerous black bands. Principal fracture, slaty, inclining to angular; cross fracture, cubical, with deposits of carbonate of lime and iron pyrites. Streak, dull black. On the fire, agglutinates a little. Ash, dirty red. Specific gravity, 1·230.	31·5	68·5	5·	2·10	1·10	1·00	7·3
CUMBERLAND—								
Cumberland, No. 1	Dull black, and coarse grained. Fracture, rough and hackley, inclining to cubical; cross fracture, slaty and angular. Streak, dull black. On the fire, agglutinates and swells a little. Ash, dirty white. Specific gravity, 1·294.	25·5	74·5	2·1	1·30	·70	·60	2·8
Cumberland, No. 2	Coal black, with dull luminæ. Fracture, irregular, inclining to cubical; cross fracture, rough and angular, with charcoal deposits. Streak, black. On the fire, swells and fuses slightly. Ash, grey. Specific gravity, 1·275.	25·6	74·4	1·4	1·10	·60	·50	1·9
Cumberland, No. 3	Coal black, and coarse grained, semi-crystalline. Fracture, hackley and angular, with layers of charcoal; cross fracture, irregular and angular. Streak, brownish black. On the fire, swells and agglutinates. Ash, yellow white. Specific gravity, 1·290.	30·9	69·1	4·	1·70	·80	·90	5·8

ANALYSES OF BITUMINOUS COALS—(*continued*).

Name of Coal.	General Character.	Volatile Matter.	Coke.	Ash.	Sulphur in			Ash in Coke, per Cent.
					Coal.	Coke.	Volatile Matter.	
Derbyshire— *Staveley*..........	Colour, jet black. Structure, splintry and prismatic. Fracture, slaty and columnar; cross fracture, irregular and cubical, with deposits of carbonate of lime and iron pyrites. Contains several black bands with charcoal. Streak, black. On the fire, crackles and splits; fuses slightly. Ash, dirty pale red. Specific gravity, 1·275.	40·9	59·1	2·7	1·20	·80	·40	4·57
Gloucestershire— *Coal-pit Heath*....	Colour, coal black. Structure, granular and crystalline. Fracture, coarse grained and irregular in all directions, with numerous layers of charcoal and iron pyrites, and traces of carbonate of lime. On the fire, swells and fuses slightly. Ash, brick red. Specific gravity, 1·370.	30·1	69·9	5·8	4·10	2·20	1·90	8·3
Whitecroft, near Lydney........	Coarse grained and fibrous. Principal fracture, hackley and slaty, with deposits of charcoal; cross fracture, uneven, inclining to rhomboidal, with deposits of corbonate of lime and iron pyrites. Streak, dull black. On the fire, fuses slightly. Ash, deep red. Specific gravity, 1·401.	34·3	65·7	11·1	3·10	1·90	1·20	16·8
Lancashire— *Arley*............	Colour, coal black, with shining layers. Structure, massive. Fracture, inclining to slaty, with charcoal deposits; cross fracture, cubical, with traces of carbonate of lime. On the fire, spits slightly, and intumesces. Ash, dull fawn colour. Specific gravity, 1·270.	33·7	66·3	3·6	1·20	·60	·60	4·8

ANALYSES OF BITUMINOUS COALS—(*continued*).

Name of Coal.	General Character.	Volatile Matter.	Coke.	Ash.	Sulphur in			Ash in Coke, per Cent.
					Coal.	Coke.	Volatile Matter.	
Lancashire—								
St. Helen's ……	Coal black and laminated. Principal fracture, slaty; cross fracture, cubical, with numerous deposits of charcoal in the principal fracture, and carbonate of lime in the cross fracture. Streak, dull black. On the fire, swells and agglutinates. Ash, fawn colour. Specific gravity, 1·285.	37·2	62·8	1·2	1·10	·54	·56	1·91
Northumberland and Durham—								
Blenkinsopp ……	Coal black; laminated. Fracture, coarse and granular; cross fracture, splintry, inclining to cubical. Streak, dull black. On the fire, fuses slightly and intumesces. Ash, grey. Specific gravity, 1·298.	38·	62·	5·1	1·60	·80	·80	8·2
Dean's Primrose ..	Colour, brownish black, with shining layers. Fracture, in all directions, cubical and somewhat irregular, with occasional deposits of iron pyrites. On the fire, splits, and crackles slightly, swells, and intumesces. Ash, brick red. Specific gravity, 1·261.	29·25	70·75	2·4	1·40	·71	·69	3·4
Garesfield (*Butes'*)	Coal black and rather friable, with thin bands of dark laminæ throughout. Fracture, uneven and cubical; cross fracture, angular and hackley, containing traces of charcoal. Streak, dull black. On the fire, swells and fuses together. Ash, light red. Specific gravity, 1·290.	28·3	71·7	3·2	·90	·40	·50	4·4

ANALYSES OF BITUMINOUS COALS—(*continued*).

Name of Coal.	General Character.	Volatile Matter.	Coke.	Ash.	Sulphur in			Ash in Coke, per Cent.
					Coal.	Coke.	Volatile Matter.	
NORTHUMBERLAND AND DURHAM— *Garesfield* (*Cowan's*)	Coal black and shining, with thin dark laminæ. Fracture, irregular and cubical; cross fracture, angular, and affording deposits of charcoal. Streak, dull black. On the fire, aggluminates, swells, and partially fuses. Ash, pale cream colour. Specific gravity, 1·259.	29·4	70·6	·95	·85	·40	·45	1·3
Gosforth	Coal black, with shining layers. Fracture, irregular, inclining to cubical; cross fracture, cubical, with indications of charcoal. Streak, dull black. On the fire, swells and agglutinates. Ash, dull yellow. Specific gravity, 1·260.	35·	65·	1·	1·10	·50	·60	1·5
Hastings Hartley ..	Jet black; laminated, and splintry. Fracture, cubical, and slightly conchoidal; cross fracture, cubical and irregular. Streak, black, with a shade of brown. On the fire, cracks and splits, with a trifling tendency to agglutinate. Ash, white, with red streaks. Specific gravity, 1·278.	36·6	63·4	2·	·95	·50	·45	3·1
West Hartley	Jet black, with thin dull laminæ in the direction of the principal fracture, and slight deposits of charcoal. Fracture, slaty, cubical, inclining to conchoidal; cross fracture, cubical, with layers of carbonate of lime. Streak, brown black. On the fire, splits and opens, but does not fuse. Ash, dull cream colour. Specific gravity, 1·269.	35·8	64·2	4·7	1·10	·60	·50	7·3

ANALYSES OF BITUMINOUS COALS—(*continued*).

Name of Coal.	General Character.	Volatile Matter.	Coke.	Ash.	Sulphur in			Ash in Coke, per Cent.
					Coal.	Coke.	Volatile Matter.	
Northumberland and Durham— *Leverson's Wallsend*	Colour, coal black, with shining layers. Fracture, cubical, and slightly slaty; cross fracture, cubical, with thin layers of iron pyrites. Streak, black and shining. On the fire, opens out, and agglutinates. Ash, brick red. Specific gravity, 1·278.	34·9	65·1	4·9	1·30	·65	·65	7·52
South Peareth	Dull black, with bright luminæ, coarse grained. Fracture, irregular, hackley, and inclining to cubical, with charcoal deposits; cross fracture, cubical. Streak, dull black. On the fire, intumesces and fuses partially. Ash, light yellow. Specific gravity, 1·266.	27·8	72·2	1·8	1·20	·60	·60	2·5
Pelaw Main	Colour, coal black, inclining to jet in variable layers. Fracture, cubical in all directions, with deposits of pyritic charcoal and carbonate of lime. On the fire, opens out, agglutinates, and intumesces. Ash, pale fawn colour. Specific gravity, 1·271.	30·3	69·7	2·60	1·20	·70	·50	3·7
Pelton Main	Colour, coal black, with shining layers. Fracture, in both directions cubical, with their deposits of carbonate of lime, and iron pyrites in the cross fracture. Streak, black and shining. On the fire, opens out, and fuses slightly. Ash, pale ochry yellow. Specific gravity, 1·270.	28·4	71·6	1·41	1·10	·62	·48	1·96

ANALYSES OF BITUMINOUS COALS—(*continued*).

Name of Coal.	General Character.	Volatile Matter.	Coke.	Ash.	Sulphur in			Ash in Coke, per Cent.
					Coal.	Coke.	Volatile Matter.	
NORTHUMBERLAND AND DURHAM—								
New Pelton	Colour, coal black, inclining to jet in layers. Fracture, slaty and cubical; cross fracture, irregular and cubical. Streak, black and shining. On the fire, opens out, fuses slightly, and intumesces. Ash, light brick red. Specific gravity, 1·265.	30·2	69·8	1·75	1·10	·56	54·	2·5
South Tyne	Shining black, with dull laminæ. Fracture, somewhat rhomboidal and irregular, with layers of charcoal and pyrites; cross fracture, angular. Streak, dull brownish black. On the fire, agglutinates and swells slightly. Ash, deep pink. Specific gravity, 1·339.	36·3	63·7	3·9	2·10	1·10	1·00	6·1
Urpeth	Colour, coal black, with shining layers. Fracture, in all directions, cubical, with layers of carbonate of lime and iron pyrites on the cross fracture. Streak, black and shining. On the fire, opens out, swells, and fuses slightly. Ash, dull ochry yellow. Specific gravity, 1·271.	28·7	71·3	1·35	1·00	·60	·40	1·89
Washington	Colour, coal black, with shining layers. Fracture, in all directions, cubical and irregular. On the fire, opens out and fuses slightly. Streak, shining black. Ash, reddish yellow. Specific gravity, 1·260.	31·25	68·75	2·2	1·30	·67	·63	3·2

ANALYSES OF BITUMINOUS COALS—(*continued*).

Name of Coal.	General Character.	Volatile Matter.	Coke.	Ash.	Sulphur in			Ash in Coke, per Cent.
					Coal.	Coke.	Volatile Matter.	
SOMERSETSHIRE— *Nailsea*	Dull black, coarse grained, and fibrous. Fracture, hackley, inclining to rhomboidal, with numerous deposits of charcoal and iron pyrites; cross fracture, very irregular. Streak, brown black. On the fire, swells and fuses together. Ash, flesh-coloured, with red streaks. Specific gravity, 1·312.	34·9	65·1	3·	2·85	1·50	1·35	4·6
Radstock	Colour, dull black. Structure, coarse grained and irregular. Fracture, slightly slaty; cross fracture, hackley, inclining to cubical, with layers of charcoal and iron pyrites, in cubical crystals; deposits of carbonate of lime. Streak, dull black. On the fire, alters but little, and intumesces slightly. Ash, dull yellow and floculent. Specific gravity, 1·275.	38·25	61·75	3·5	3·10	1·80	1·30	5·6
STAFFORDSHIRE— *Apedale, 4 Feet*....	Jet black, and in square, splintry fragments. Principal fracture, slaty, and slightly conchoidal; cross fracture, irregular, and numerous black bands. On the fire, decrepitates and opens; does not fuse. Ash, deep fawn colour. Specific gravity, 1·267.	40·	60·	·75	·80	·38	·42	1·25

ANALYSES OF BITUMINOUS COALS—(*continued*).

Name of Coal.	General Character.	Volatile Matter.	Coke.	Ash.	Sulphur in			Ash in Coke, per Cent.
					Coal.	Coke.	Volatile Matter.	
Staffordshire—								
Apedale	Jet black and laminated; splintry and hard. Principal fracture, slaty; cross fracture, irregular and angular, inclining to cubical.. Streak, shining black. On the fire, crackles and burns freely, but remains open, without any symptoms of fusion. Ash, deep red. Specific gravity, 1·307.	38·5	61·5	1·9	1·50	·82	·68	3·1
Heathern	Colour, dull black, with shining layers. Fracture, slaty, containing deposits of charcoal; cross fracture, cubical, with thin layers of carbonate of lime and iron pyrites. On the fire, splits and fuses slightly. Ash, pale dull yellow. Specific gravity, 1·280.	42·9	57·1	1·75	1·50	·70	·80	3·
Silverdale, 10 *Ft*...	Splintry and laminated. Principal fracture, slaty; cross fracture, angular, and slightly conchoidal. Streak, dull black. On the fire, splits and crackles slightly; does not fuse. Ash, dull red. Specific gravity, 1·301.	34·	66·	1·95	1·30	·70	·60	2·92
Woodshutts, 7 *Ft*., *Banbury*	Fibrous and coarse grained. Principal fracture, hackley; cross fracture, irregular, inclining to rhomboidal, with layers of charcoal. On the fire, swells, but does not fuse. Ash, deep fawn colour. Specific gravity, 1·291.	40·2	59·8	1·22	·90	·54	·36	2·03

ANALYSES OF BITUMINOUS COALS—(*continued*).

Name of Coal.	General Character.	Volatile Matter.	Coke.	Ash.	Sulphur in			Ash in Coke, per Cent.
					Coal.	Coke.	Volatile Matter.	
Wales (North)—								
Ruabon, Top Yard Seam	Coal black, with shining layers; laminated. Fracture, slaty and cubical, with charcoal deposits; cross fracture, cubical. Streak, black. On the fire, swells and agglutinates. Ash, pale fawn colour. Specific gravity, 1·269.	37·5	62·5	2·5	1·40	·80	·60	4·
Ruabon, Main Coal	Coal black, and laminated. Fracture, irregular, inclining to cubical; cross fracture, foliated and splintry, with numerous layers of charcoal, and some indications of iron pyrites. Streak, dull black. On the fire, swells and fuses together. Ash, pale yellow. Specific gravity, 1·284.	41·5	58·5	1·	·85	·45	·40	1·7
Ruabon, Yard Seam	Coal black, with dull laminæ. Fracture, irregular, inclining to cubical; cross fracture, angular, with considerable deposits of charcoal, and thin layers of carbonate of lime. Streak, dull black. On the fire, agglutinates and intumesces. Ash, fawn colour. Specific gravity, 1·271.	34·	66·	1·4	1·10	·60	·50	2·1
Ruabon, Nant Seam	Shining black, and in columnar concretions. Fracture, coarse and hackley, with charcoal deposits; cross fracture, rhomboidal and crystalline, with thin layers of carbonate of lime. Streak, black. On the fire, agglutinates slightly and intumesces. Ash, cream colour. Specific gravity, 1·269.	37·9	62·1	1·4	1·10	·70	·40	2·2

ANALYSES OF BITUMINOUS COALS—(*continued*).

Name of Coal.	General Character.	Volatile Matter.	Coke.	Ash.	SULPHUR IN			Ash in Coke, per Cent.
					Coal.	Coke.	Volatile Matter.	
WALES (SOUTH)—								
Rhonda	Colour, coal black. Structure, coarse grained. Fracture, slaty and irregular; cross fracture, hackley and angular. On the fire, swells slightly. Ash, light fawn colour. Specific gravity, 1·278.	22·8	77·2	2·7	2·30	1·20	1·10	3·5
Rhonda, Low Main	Colour, coal black; coarse grained and hackley. Fracture, irregular and slightly cubical; cross fracture, rough and angular. Streak, dull black. On the fire, intumesces and agglutinates feebly. Ash, pale red. Specific gravity, 1·280.	23·1	76·9	2·1	2·20	1·10	1·10	2·7
YORKSHIRE—								
Elsecar Low Pit ..	Colour, jet black, with dull layers. Structure, laminated. Fracture, slaty, inclining to cubical; cross fracture, cubical, with numerous deposits of charcoal, and traces of carbonate of lime. Streak, black. On the fire, swells and fuses with some intumescence. Ash, ochry yellow. Specific gravity, 1·258.	37·	63·	1·1	1·20	·63	·57	1·74
Grigleston Cliff, Soft	Colour, coal black. Structure, splintry, and in layers. Fracture, slaty, with bands of charcoal; cross fracture, hackley and cubical, containing traces of carbonate of lime. Streak, black. On the fire, alters but little, and does not fuse or decrepitate. Ash, brick red. Specific gravity, 1·255.	35·6	64·4	1·6	1·40	·75	·65	2·48

ANALYSES OF BITUMINOUS COALS—(*continued*).

Name of Coal.	General Character.	Volatile Matter.	Coke.	Ash.	SULPHUR IN			Ash in Coke, per Cent.
					Coal.	Coke.	Volatile Matter.	
YORKSHIRE—								
Mortomly	Coal black, with shining layers, in splintry fragments. Fracture, laminated and cubical; cross fracture, cubical and irregular. Streak, dull black. On the fire, splits and opens, but afterwards agglutinates and intumesces. Ash, light fawn colour. Specific gravity, 1·220.	37·	63·	1·6	1·10	·60	·50	2·5
Silkston, No. 1....	Colour, jet black. Structure, laminated and prismatic. Fracture, slaty; cross fracture, cubical and irregular, with deposits of carbonate of lime and charcoal. Streak, black and shining. On the fire, splits and fuses slightly. Ash, fawn colour. Specific gravity, 1·260.	34·1	65·9	2·78	1·30	·80	·50	4·2
Silkston, No. 2....	Colour, jet black. Structure, uniform. Fracture, in all directions cubical; traces of carbonate of lime and charcoal. Streak, brownish black. On the fire, fuses slightly, and intumesces. Ash, yellowish fawn colour. Specific gravity, 1·259.	38·	62·	2·55	1·10	·60	·50	4·1
Silkston, No. 3....	Colour, coal black. Structure, laminated and prismatic. Fracture, slaty and columnar; cross fracture, irregular and cubical, with deposits of charcoal and traces of carbonate of lime. Streak, black. On the fire, alters little. Ash, pale fawn colour. Specific gravity, 1·262.	35·2	64·8	2·8	1·45	·75	·70	4·1

ANALYSES OF BITUMINOUS COALS—(*continued*).

Name of Coal.	General Character.	Volatile Matter.	Coke.	Ash.	Sulphur in			Ash in Coke, per Cent.
					Coal.	Coke.	Volatile Matter.	
Yorkshire— *Soap House Pit*....	Dull black and slaty, with impressions of leaves. Fracture, rough and hackley, inclining to conchoidal; cross fracture, irregular and angular. On the fire, splits, and then agglutinates and swells. Streak, dull brownish black. Ash, light brown. Specific gravity, 1·258.	35·	65·	·8	·75	·40	·35	1·2
Woodthorpe	Compact, black and uniform in appearance; resembles Cannel coal. Fracture, conchoidal; cross fracture, splintry and conchoidal, with layers of carbonate of lime. Streak, black. On the fire, decrepitates slightly and splits, but does not fuse. Ash, dirty pink. Specific gravity, 1·347.	33·1	66·9	10·5	1·20	·70	·50	16·6
France— *Denain* (*Valenciennes*)........	Colour, coal black. Structure, coarse grained and slightly fibrous. Fracture, irregular, inclining to cubical, with layers of charcoal; cross fracture, hackley and angular, with traces of iron pyrites. On the fire, but little affected, intumesces and agglutinates. Ash, fawn colour. Specific gravity, 1·265.	29·9	70·1	6·	2·4	1·30	1·10	8·57

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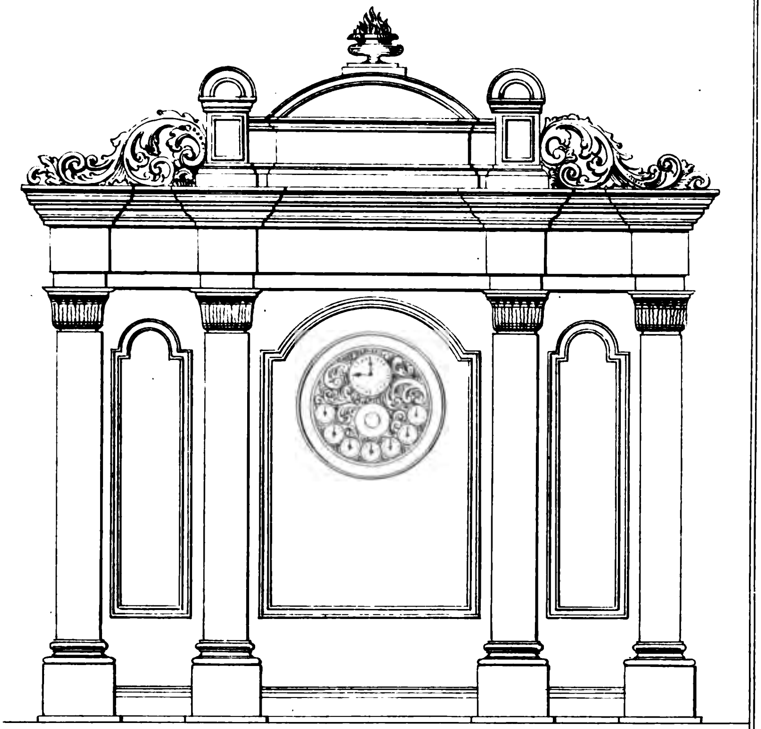

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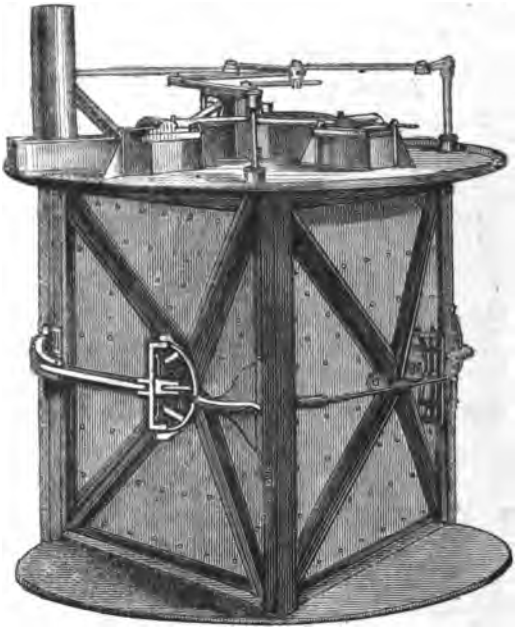

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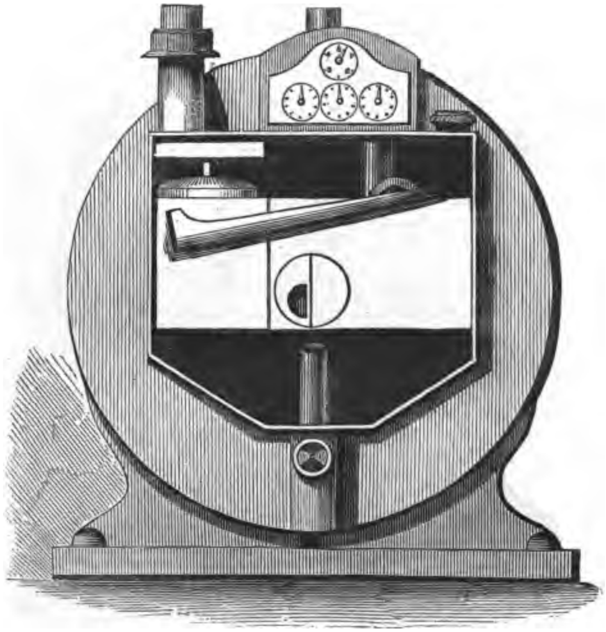
IMPROVED

COMPENSATING WATER METER.



LIST OF PRICES.

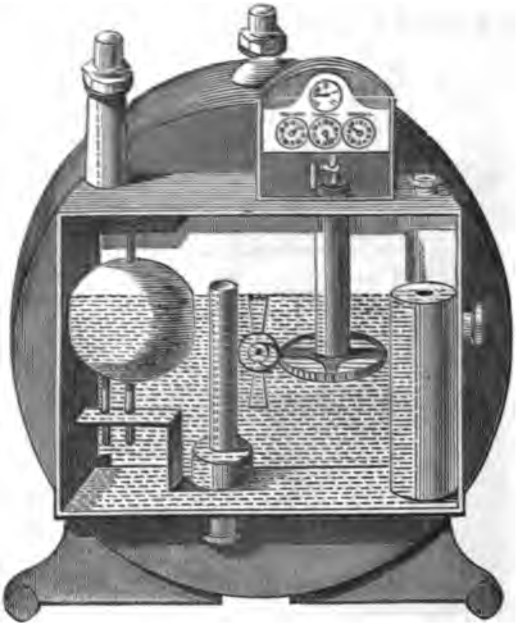
	£	s.	d.		£	s.	d.
2 Lights ..	1	14	0	50 Lights ..	8	10	0
3 " ..	2	2	0	60 " ..	11	10	0
5 " ..	2	10	0	80 " ..	14	10	0
10 " ..	3	5	0	100 " ..	18	10	0
20 " ..	4	7	0	150 " ..	22	10	0
30 " ..	5	17	0				

Terms,.................. *Discount,*..................

WM. SUGG, 19 & 20, MARSHAM STREET, WESTMINSTER.

PRIZE MEDAL.—London, 1862.—Class 31, Sec. B.
(Meters, Governors, and Burners.)

ORDINARY & WATER-BOX METERS.



LIST OF PRICES.

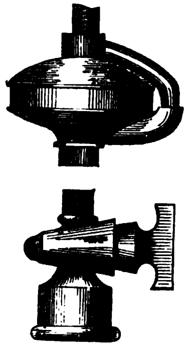
		£	s.	d.			£	s.	d.
2 Lights	..	1	14	0	50 Lights	..	8	10	0
3 „	..	2	2	0	60 „	..	11	10	0
5 „	..	2	10	0	80 „	..	14	10	0
10 „	..	3	5	0	100 „	..	18	10	0
20 „	..	4	7	0	150 „	..	22	10	0
30 „	..	5	17	0					

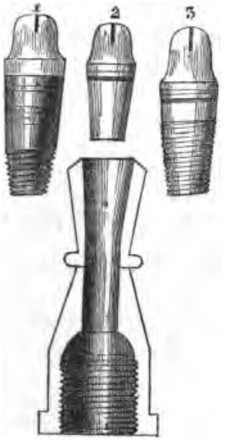
Terms,.................. *Discount*,..................................

WM. SUGG, 19 & 20, MARSHAM STREET, WESTMINSTER.

PRIZE MEDAL.—London, 1862.—Class 31, Sec. B. (Meters, Governors, and Burners.)

PUBLIC LAMP GOVERNORS,





FOR MAINTAINING A UNIFORM PRESSURE AT THE BURNERS IN PUBLIC LAMPS.

Many thousands of these Governors have been in satisfactory operation, for periods varying from three years, without any apparent sign of depreciation, and when fitted with Lava, or other incorrodible burners, the desired consumption per lamp is maintained with very great regularity; while, in consequence of the easy flow given to the Gas, and the prevention of excess of pressure, joined to the careful cutting and superior make of the burners, the illuminating power is materially increased, frequently to the extent of three or four candles.

WM. SUGG, 19 & 20, MARSHAM STREET, WESTMINSTER.

[PRICE LIST OVER.

PRIZE MEDAL.—London, 1862.—Class 31, Sec. B. (Meters, Governors, and Burners.)

PRICE LIST.

	£	s.	d.
Governors, adjusted to maintain $\frac{5}{10}$, $\frac{6}{10}$, or $\frac{8}{10}$ of an inch pressure, ready for fixing, per doz. . .	1	14	0
Lantern Cocks, pattern as above, per doz.	0	15	6
Slip cones, "Imperial System," per doz. . . .	0	3	0
Ditto, same pattern (long), according to length, per doz.			

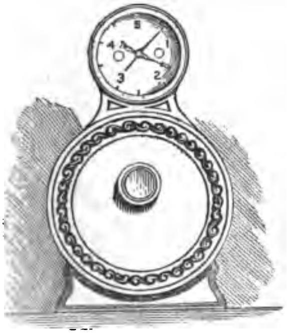
PROVED BY GAS.

	£	s.	d.	
Lava Burners, No. 1 pattern, to burn 5 ft. per hour at $\frac{5}{10}$, Iron Cased . . . . per gross	1	4	0	For Public Lamps with Governors.
No. 1, ditto, ditto, Brass Cased, per gross	1	7	0	
No. 2, Imperial Pattern, to burn 4 ft. or 5 ft. per hour, at $\frac{8}{10}$ . . . . . . per gross	1	0	0	
No. 3 Ordinary Lava burner to burn 4 ft. or 5 ft., at $\frac{8}{10}$	1	0	0	

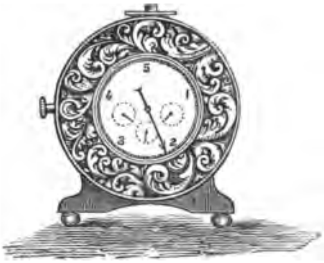
NOT PROVED.

	£	s.	d.
Burners of any other pattern, to order, Uncased .	0	16	0
Ditto, ditto, Cased in Iron . . .	1	0	0
Ditto, ditto, Cased in Brass . .	1	3	0

PRIZE MEDAL.—London, 1862.—Class 13.
(Photometrical Apparatus.)



No. 1.



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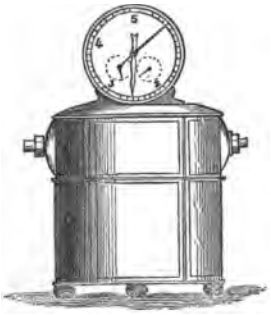

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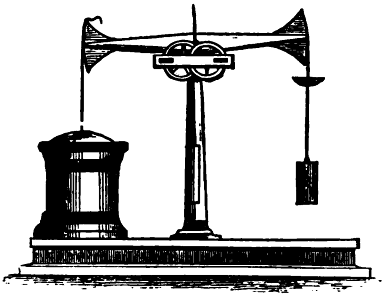

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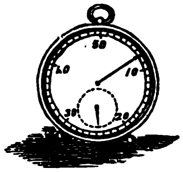

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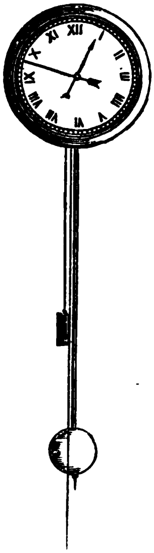

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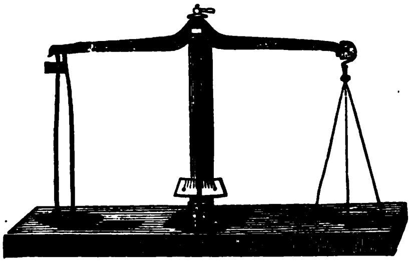

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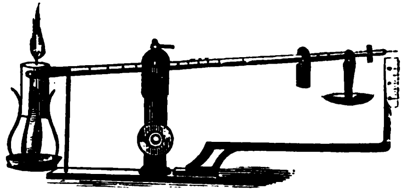

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WM. SUGG, 19 & 20, MARSHAM STREET, WESTMINSTER.

PRIZE MEDAL.—London, 1862.—Class 13. (Photometers and Apparatus.)

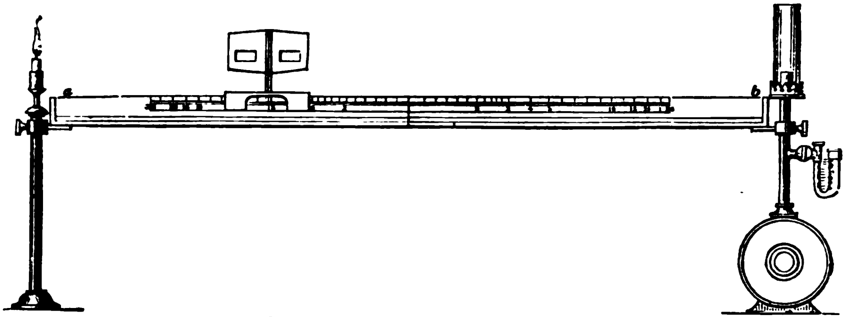
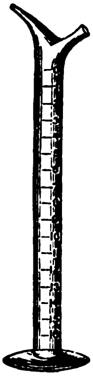


Fig. G.—Ordinary Bunsen Photometer.



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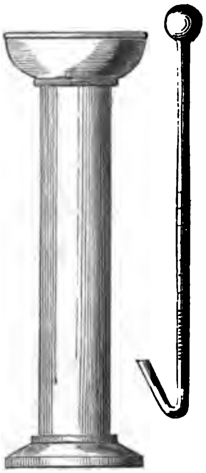

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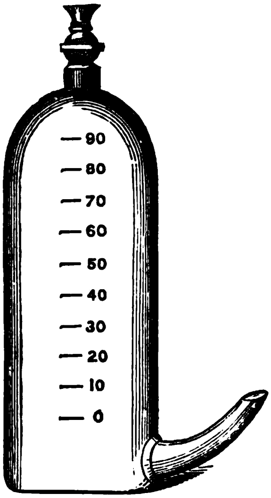

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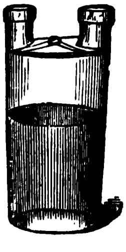

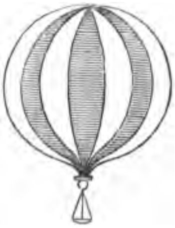

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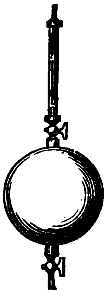
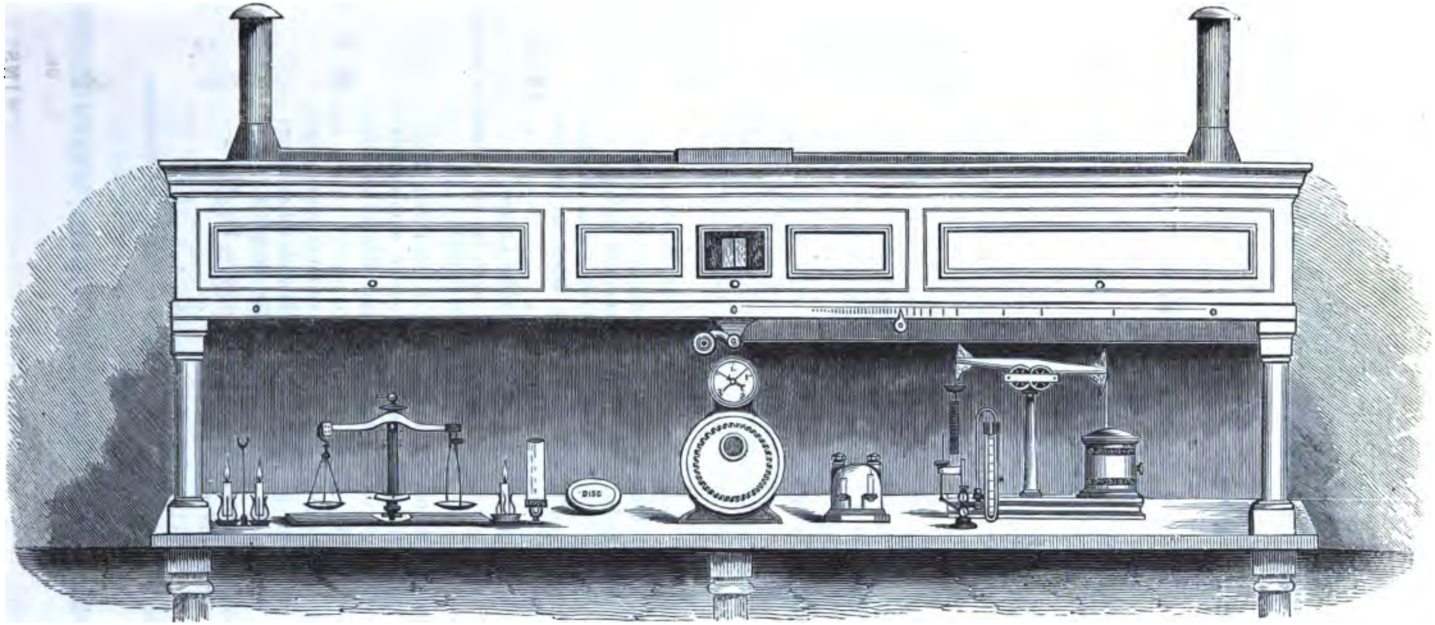


No. 28.

THE EVANS PHOTOMETER,



With Apparatus, as used in the various Districts of London, for testing the Illuminating Power of the Gas supplied under the Metropolis Gas Act—consisting of Experimental Meter, with Clock Index; Balance Governor; Pressure Pillar; Scales; Single and Double Candle Holders; Argand Burners; Discs, &c.

PRIZE MEDAL.—London, 1862.—Class 13.
(Photometers and Apparatus.)

PRICES
FOR
PHOTOMETRIC APPARATUS.

	£	s.	d.
A.—Standard "Evans" Photometer, 100-inch scale, in French-polished white pine, lined throughout with black velvet, with disc frame, slide (central adjustment), and ventilators, complete (*see* Fig. A)	15	15	0
Ditto, fitted for gas at both ends, and provided with double scales and slides (central adjustment)	16	16	0
B.—"Evans" Photometer, 75-inch scale, fitted exactly as above	16	16	0
C.—"Evans" Photometer, 50-inch scale, in French-polished dark-coloured pine, lined throughout with black velvet, single scale, gas at one end only, with slide (central adjustment) and ventilators, complete (Fig. C) (*Suitable for small Gas Works.*)	8	0	0
D.—Portable "Evans" Photometer, shuts up into a space of 3 feet by 1 foot by 10 inches, dark mahogany-coloured pine, lined with black velvet inside, candle slide and single scale, fitted for gas at one end, complete (*Can be used to try Public Lamps.*)	10	10	0

[The above Photometers require no dark room, but can be used in the open air if necessary, by daylight.]

	£	s.	d.
E.—100-inch (Bunsen) Photometer, with improved sight box, mahogany standards, gas pillar, with double cock, micrometer adjustment, and slide for candle, complete	6	6	0
F.—60-inch Photometer (Dr. Letheby's system), mahogany standards, gas pillar, with double cock, micrometer adjustment, and slide for candle, complete	6	6	0
G.—Ordinary (Bunsen) 100-inch Photometer, Fig. G, exclusive of meter gas pillar	3	3	0

[These Photometers require a dark room.]

☞ **The above Prices are exclusive of Meters and Governors.**

WM. SUGG, 19 & 20, MARSHAM STREET, WESTMINSTER.

PRIZE MEDAL.—London, 1862.—Class 13.
(Photometers and Apparatus.)

	£	s.	d.
1.—Experimental Meter, capacity 144 cubic inches, combination index, minute clock and gas index working on one dial, 5 feet hourly rate of consumption and time circle, small circles showing 5 feet actual consumption and 10 minutes. The Meter fitted with brass water-gauge. The Minute Clock, with lever escapement, dead beat, provided with bell, which is struck every minute, handsomely japanned (*see* Fig. 1) . . .	10	10	0
(*This Meter much facilitates observations of* 5 *feet per hour, &c.*)			
2.—Experimental Meter, capacity $\frac{1}{12}$ of a foot, with index showing hourly and actual rate of consumption, circular spirit level, and water-gauge, japanned and ornamented	5	5	0
3.—Experimental Meter, centre dial showing hourly rate of consumption only, capacity $\frac{1}{12}$ of a foot, japanned (*see* Fig. 3)	4	4	0
4.—Small Experimental Meter to fit inside portable Photometer, with level and water-gauge, complete .	4	4	0
5.—Dry Experimental Meter, screwed pannels, and top index, showing hourly and actual rate of consumption (capacity 144 inches) per revolution (*see* Fig. 5)	11	11	0
6. — First quality Balance Governor, with parabolic valve, 3-inch stroke, thick white metal incorrodible tank and gasholder, balance and turned balance weights, and shot scale, complete, accurately adjusted and handsomely japanned, mounted upon French-polished base (*see* Fig. 6) . . .	4	4	0
7. — Second quality, fitted as above, but without base, painted	3	3	0
These Governors will stand a pressure of 6 *inches without blowing.*			
8. — Ordinary Balance Governor, 2½-inch stroke, metal tank and gasholder, steel knife edge, and balance weights, complete	2	2	0

PRIZE MEDAL.—London, 1862.—Class 13. (Photometers and Apparatus.)

	£	s.	d.
9.—Pressure Pillar, with double cocks, micrometer adjustment, and 6-inch pressure gauge, with ivory scale, lacquered, complete	2	5	0
10.—Minute Clock, 8-day movement, 40-inch pendulum, dead beat, hour, minute, and second hands, in rosewood case, complete, strikes each *minute*	6	6	0
11.—Minute Clock, 30-hour movement, 40-inch pendulum, dead beat, second hand, mahogany case, complete, strikes each minute (Fig. 11)	4	4	0
12.—Small Minute Stop Clock (portable), 4-inch dial, divided into 50 divisions, to suit 5 feet per hour calculations, lever escapement, jewelled in two holes, strikes each minute (Fig. 12)	3	15	0
13.—Balance, with horse-shoe beam, pointer and graduated scale, mahogany base, set of grain weights, from ¼ to 500 grains, complete, suitable for weighing the candle whilst burning (Fig. 13)	6	0	0
14.—Candle Balance, to weigh the candle whilst burning, graduated bar, divided into 13 grains, each grain being ⅜-inch wide, to weigh to the 10th part of a grain, with balance weight, complete (Fig. 14)	3	10	0
15.—Ordinary Scales in Box, glass pan, and set of grain weights, complete	2	0	0
16.—Set of aluminium weights, from ⅒ of a grain up to 10 grains, complete, per set	0	3	0
17.—Set of brass grain weights, from ⅒ of a grain up to 10 grains, per set	0	1	6

PRIZE MEDAL.—London, 1862.—Class 13.
(Photometers and Apparatus.)

	£	*s.*	*d.*
18.—Candle holder for one candle, with cone and socket.	0	5	6
19.—Ditto, ditto, for two candles	0	11	0
20.—Parliamentary Standard Tested Argand 15-hole Burner, lava top and 7-inch chimney, complete (*This Burner is used for Photometrical purposes in England, the continent, and America*).	0	5	6
20b.—Lava Batwing Burner and cone, complete, for Cannel gas	0	1	0
20c.—Small Burner Pliers (bright steel) . . .	0	2	6
21.—Greased or Leeson Star discs, best quality, per doz.	0	12	0
22.—Japanned disc box, disc in gold letters, each . .	0	2	0
22b.—Japanned shot or sand boxes, written in gold letters, each.	0	1	0
23.—Sperm candles, best quality, suitable for Photometrical purposes, best quality, about 120 grains per hour			
24.—Test papers—Turmeric, Acetate of Lead, Litmus, Reddened Litmus, per doz books . . .	0	2	0
25.—Ammonia and Sulphur Test Glass, fitted complete, (*see* Fig. 25)	1	5	0
25b.—Thermometers, on boxwood scales . . .	0	2	6
25c.—Bent or straight Thermometers, for inserting in Condensers, Hydraulic Mains, &c., mounted on brass, ready to screw in . . . . each	0	16	0
Photometrical Tables, drawn on Roller, and Varnished	0	12	0
Plain Sheet	0	5	0

THE BROMINE TEST.

	£	s.	d.
26.—Eudiometer Tube, with globular top, accurately divided (Fig. 26)	0	10	6
26b.—Improved Condenser for Eudiometer	1	0	0
26c.—Glass Syringe for Bromine	0	5	0
26d.—Bromine Bottle, capped, 1 oz.	0	2	6
Bromine (best quality guaranteed), per oz.	0	2	6
Fused Potash do., per oz.	0	0	6
Sulphate of Copper do., per lb.	0	1	0
Lewis Thompson's Eudiometer, fitted complete, Fig.	1	10	0

AMMONIA.

	£	s.	d.
27.—Alkalimeter, for ascertaining the strength of ammoniacal liquor, accurately divided	0	5	6
27b.—Litmus Test papers, per dozen books	0	2	0
27c.—Sulphuric Acid, Specific Gravity (1845), per oz.	0	0	6
Do. Bottle Capped, 8 oz.	0	7	6

SPECIFIC GRAVITY APPARATUS.

	£	s.	d.
28.—Dr. Letheby's Specific Gravity Globe, fitted complete (*see* Fig. 28)	1	15	0
29.—Wright's Specific Gravity Apparatus, balloon, thermometer, and weights, complete	2	2	0

BISULPHIDE OF CARBON APPARATUS.

	£	s.	d.
30.—"Evans" Bisulphide of Carbon Test, with motive power meter and condenser, &c., complete			
Exclusive of Experimental Meter			
31.—Dr. Letheby's Bisulphide of Carbon Apparatus, exclusive of Experimental Meter	2	10	0
32.—Woulfe's Bottles (Fig. 32), each	0	3	0

TEST GASHOLDERS.

	£	s.	d.
33.—5-foot Gasholder, best quality, in cast-iron tank, with cycloidal balance and counterpoise double scales, accurately graduated	28	0	0
34.—10-foot ditto, ditto ditto	38	0	0

EXPERIMENTAL CARBONIZING APPARATUS.

	£	s.	d.
To Carbonize the one-thousandth part of a ton, with condenser, purifier, and gasholder, &c., complete	55	0	0

PHOTOMETRICAL TABLES,

PREPARED BY

WILLIAM SUGG,

ASSOC. INST. CIVIL ENGINEERS,

FOR FACILITATING EXPERIMENTS TO DETERMINE THE ILLUMINATING POWER OF GAS.

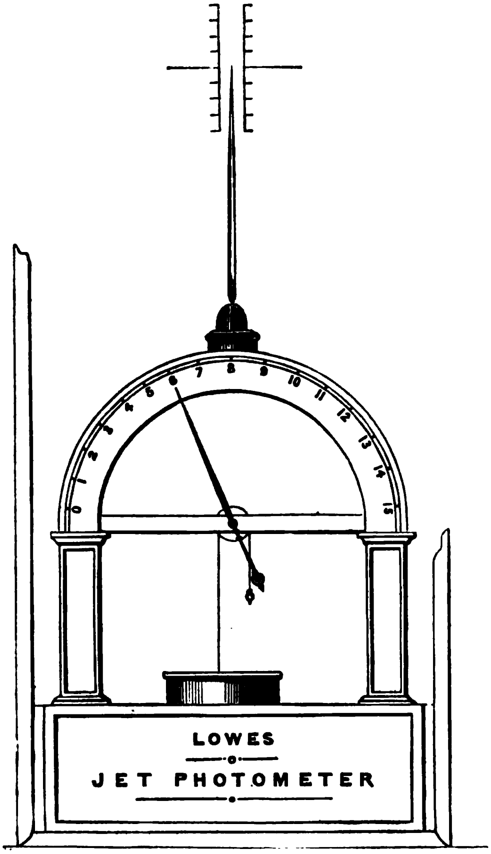
Printed on large Sheet, plain, unmounted, 5s.; Drawn on Roller, and Varnished, 12s.

Extract from "Journal of Gas Lighting," of Nov. 4th, 1862.

"A very elaborate and useful series of tables, for facilitating calculations of the results of photometrical experiments, has been constructed and published by Mr. Sugg. The first, or general table, is calculated to show the value, in standard candles, which a given quantity of gas bears to 1 candle, burning from 110 to 135 grains per hour. The rest of the tables are founded upon this one, and are arranged very conveniently. They are twelve in number, and are divided into twenty-seven columns each, the first of which contains the number of cubic feet of gas consumed per hour, increasing in tenths of a cubic foot from 4·5 to 5·5. The heading to each of the other columns indicates the number of grains per hour consumed by the sperm candle from 110 to 135 grains; and underneath, in each of these columns, and opposite to the quantity of gas recorded by the experimental meter, will be found the value, in standard candles, of the gas burned at the rate of 5 cubic feet per hour—all further calculations being thereby rendered unnecessary. The tables are mounted on cloth, with roller, &c., and form a very necessary appendage in the photometrical room."

PRIZE MEDAL.—London, 1862.—Class 13.
(Photometers and Apparatus.)

THE JET PHOTOMETER,



FOR SHOWING THE APPROXIMATE VALUE OF THE ILLUMINATING POWER OF COAL GAS (CANNEL OR COMMON).

* * *

This Instrument is constructed upon a principle discovered by Mr. Geo. Lowe, and verified by numerous observations made by him during some years past. It will be found of great service to

---

WM. SUGG, 19 & 20, MARSHAM STREET, WESTMINSTER.

Engineers, as affording at all times a good practical indication of the quality and purity of the gas manufactured under their superintendence. The Instrument consists of a very delicate pressure gauge, the scale of which is capable of showing clearly the 100th of an inch of pressure. Upon the top of the arch, which is made to serve as a gasway, is fixed a small jet burner, the height of whose flame is taken as a guide whereby to estimate the approximate illuminating power of the gas which is passing through it: the principle asserted by Mr. Lowe being that the height of a jet of gas issuing from an aperture of fixed dimensions, burning under a given pressure, is constant, if the purity and illuminating power of that gas remain the same, and that a regular increase and decrease of height is observable within certain limits corresponding to the increase or decrease in illuminating power of such gas.

The entire apparatus is enclosed in a box, having a glass front, provided with a proper ventilator to carry off the products of combustion. By this means, the jet is protected from currents of air, which much interfere with the accuracy of the observations, and the apparatus is preserved from dust.

The front of the glass is scaled off at the height of the jet, similar to a corresponding scale attached to the back of the box, both scales being parallel to each other.

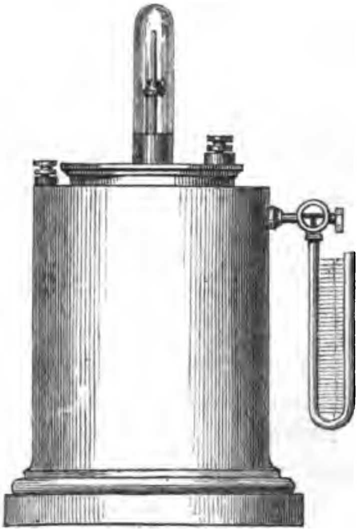
This arrangement renders it easy to determine the exact height of the jet, and every Engineer will, for himself, ascertain the exact point which corresponds to the proper standard quality of the gas manufactured at his works, whatever that standard may be.

Price, ready for service:—

	£	*s.*	*d.*
In French-polished pine case, glass front, scaled off, and back scale, small dry governor, and shut-off cock and ventilator, complete . .	6	0	0
Without case, small dry governor and shut-off cock, wire pointer	3	5	0

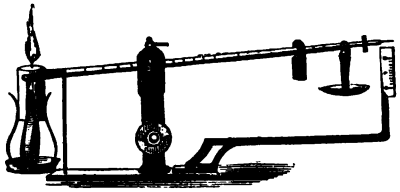
ELECTRIC ALARUM.

Electric alarum. Notwithstanding the very ingenious arrangement which has been in operation for many years at most large gasworks, for preventing the mixture of air with gas, by means of a butterfly valve and governor on the inlet of the exhauster, it was still felt desirable that some further precaution should be taken against so serious a casualty. Mr. Evans, of the Chartered Gasworks, therefore, proposed to use an Electric Alarum, which should ring a bell when the pressure or vacuum on the hydraulic main exceeded a certain fixed limit. A small battery and alarum, similar to those used by the Telegraph Company, are connected with an annular pressure gauge. This gauge consists of two cylinders, placed one within the other, the inner one being exactly the same area as the annulus surrounding it. Openings are left in the bottom of the inner cylinder so that the water with which this is filled to a fixed line may raise it to the same level in the annulus. Upon the surface of the water there is a float carrying a wire, passing through a hole in the cover. This wire has two studs attached to it, which come in contact with the cover, when the float rises and



falls to a sufficient extent in the gauge. This cover consists of a brass plate, insulated by means of gutta percha or baked wood, and has attached to it a terminal screw, to which a wire from one pole of the battery is connected; the wire from the other pole being connected through the bell instrument, to a similar terminal on the external cylinder. If this gauge, so fitted up, be connected to the hydraulic main, the float will rise or fall according to the vacuum or pressure; and upon either stud coming in contact with the brass cap, the circuit from the battery being completed, the bell will ring violently until the engineer has adjusted the exhauster. A modification of this gauge is made by Mr. Sugg. It consists of two ordinary lamp governors, to each of which a short lever is attached, carrying a counterpoise weight, so that the vacuum upon the one and the pressure upon the other can be regulated according to the will of the engineer. It is connected to the alarum and the battery in the same manner as the annular water-gauge just described. The battery contains four compartments filled with a solution of sulphate of copper; and the porous cells for the zinc plates are filled with a weak solution of sulphuric acid. £5. 10*s*.

THE CANDLE BALANCE.



Balance. This Balance is made on the principle of the Steelyard. The long arm is provided with a 10 grain weight, made of aluminium. A socket for the candle, to be used in the Photometer, is suspended on a scale from one end of the beam, which is divided into twenty-five equal parts; a steel knife-edge passes through the tenth division, and rests upon agate planes in the top of the pillar; the beam is thus divided into two unequal parts, the shorter arm comprising ten, and the longer fifteen divisions. At the end of the long arm a small dish is suspended, which is to receive the shot or sand with which the candle is counterpoised. There is also a weight capable of being moved backward or forward on a screw, projecting beyond the knife-edges from which this dish is suspended, for the purpose of adjusting the Balance. Suppose, now, the 10-grain aluminium weight to be placed on the fifteenth division of the long arm, and a sufficient quantity of shot or sand put into the dish, to balance the candle suspended in its socket, from the end of the short arm. The knife-edge is then to be lifted up from the agate planes, by turning the eccentric in the middle of the pillar; the candle and its socket may now be removed, and after being used in the Photometer, they are to be suspended as before, care being taken that none of the sperm or wax is lost during this part of the process; for every grain lost by the candle, it will be necessary to bring the 10-grain weight one division nearer to the centre of suspension. One division with the aluminium weight is equivalent to one grain. The scale is subdivided so that the candle can be balanced to one quarter of a grain with facility.

Price complete, £3. 10*s*.

PRESSURE GAUGES.

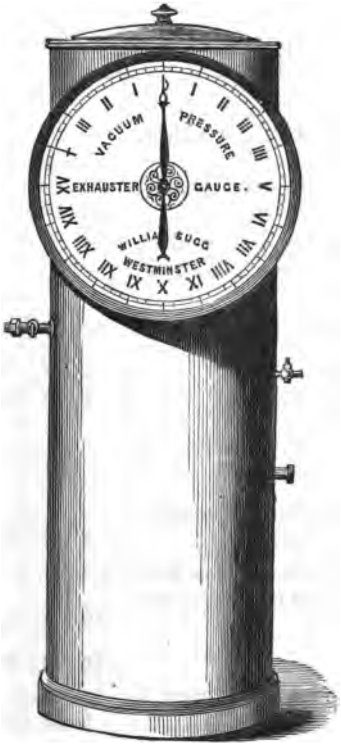
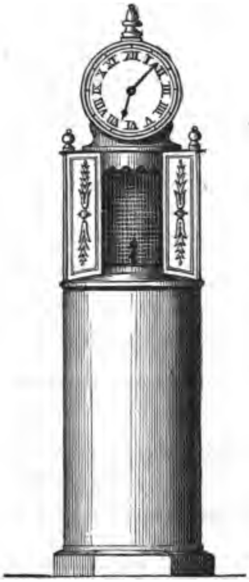
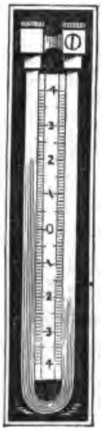


Fig. 1.—Exhauster Gauge.



No. 3.—Registering Pressure Gauge.



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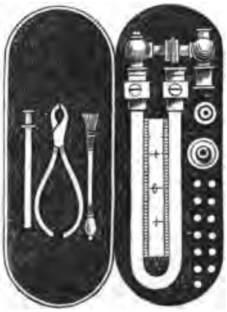

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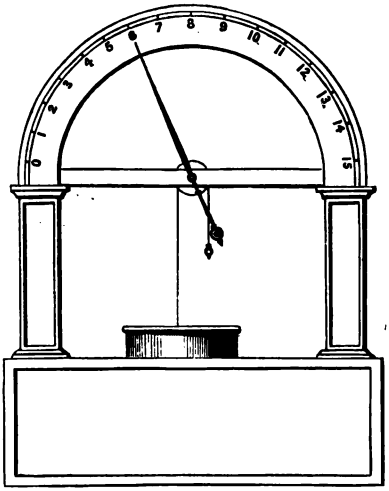

No. 5.—King's Gauge.

PRESSURE GAUGES.

	£	s.	d.
1.—Dial Exhauster Gauge, showing vacuum and pressure to 26 inches, 12-inch dial	2	18	0
Dial Exhausters made to order, with large japanned dials, black and gold or white and black, any size up to 48 inches pressure			
2.—Dial Pressure Gauge, 3 inches pressure, 4-inch dial	1	10	0
2b.—Ditto, ditto, 6 inches pressure, 9-inch dial	2	12	0
2c.—Ditto, ditto, 12 inches pressure, 9-inch dial	2	18	0

All the above are with engraved glass dials, which will clean and will not discolour.

	£	s.	d.
3.—Registering Pressure Gauge, to show 3 inches pressure, tenths actual size, with clock, complete	8	10	0
3b.—Registering Pressure Gauge, to show 3 inches pressure, enlarged scale, tenths about treble size, with 8-day clock, complete	18	0	0
3c.—Registering Exhauster Gauge	18	0	0
4.—Inspectors' Pocket Gauge, improved form, fitted in case, complete	1	15	0
5.—King's Gauge, very delicate, to show the one hundredth of an inch pressure, with enlarged scale, graduated to 1-tenth pressure	2	10	0
6.—Pressure Gauge, mounted on board, with raised moulding to protect glass, 6 inches pressure	0	18	0
6b.—Ditto, ditto, 12 inches pressure	1	0	0
6c.—Ditto, ditto, 24 inches ,,	1	5	0
7.—3-Tube Pressure Gauges, with scales, complete, ready for fixing:—			
3 inches pressure	0	6	0
6 inches ,,	0	8	0
12 inches ,,	0	10	0

All other kinds of Pressure Gauges to order.

PRIZE MEDAL.—London, 1862.—Class 31, Sec. B. (Burners, &c.)

SUN BURNERS.

For Halls, Churches, Public Buildings, &c.; constructed on the most improved system, and of best quality.

	£	s.	d.		£	s.	d.
For 20 Lights .	9	10	0	For 60 Lights .	15	0	0
„ 30 „ .	10	10	0	„ 80 „ .	18	10	0

Suitable for fixing at the level of ceiling, or otherwise.

LAVA GAS BURNERS.

These burners are confidently recommended as being superior in point of workmanship, durability, and illuminating power, to any other kind of Burner yet introduced to the notice of the public. W. Sugg has bestowed great care in the construction of his models, with a view to produce a really good Burner, and he has received the approbation of all who have used them.

They are made in the following forms, viz:—

		£	s.	d.
Pressure required, 2 to 4 tenths.	Argand Sun Ring Burners, for Shop Fronts, which burn with a steady brilliant column of flame, at the rate of about 6½ to 7 ft. per hour. Illuminating power, with common gas, 22 to 28 sperm candles	0	5	6
Do.	30-Hole Drilled Argand Burners, to consume about 6 to 7 ft. per hour. 22 to 28 candles	0	5	6
½ a tenth.	15-Hole Parliamentary Standard Burner, to burn 5 ft. per hour; common gas; equal to 12 candles. This burner is almost universally used to test the illuminating power of gas .	0	5	6
	Fine 30-Hole Burners, for cannel gas . .			
	Fine Sun Ring Burners, for ditto . . .			
	Batwing Burners, to fit in brass or iron sockets, for public lamps (*see* Public Lamp Governors).			
5 to 8 tenths.	Fishtail Burners, Lava, Nos 1 to 8, per gross .	0	16	0
	Batwing Burners, Lava, Nos. 1 to 8 . .	0	16	0
	Ornamental Lava Burners, per gross . from	0	16	0
	Iron-cased Batwing or Fishtail, per gross . .	0	18	0
	Brass-cased Lava Batwing or Fishtail, per gross	1	4	0

All other kinds and sizes of burners made to order.

WM. SUGG, 19 & 20, MARSHAM STREET, WESTMINSTER.

BEST IRON WELDED TUBES.

Names.	2 in.		1½.		1¼.		1.		¾.		½.		⅜.		¼.		⅛.		
	s.	*d.*	*s.*	*d.*	*s.*	*d.*	*s.*	*d.*	*s.*	*d.*	*s.*	*d.*	*s.*	*d.*	*s.*	*d.*	*s.*	*d.*	
Gas tubes, in lengths from 2 to 12 feet ..	1	8	1	1	0	10	0	7	0	5	0	4¼	0	3¾	0	3¾	0	3	per ft.
Pieces under 2 feet ..	3	0	2	0	1	9	1	3	1	0	0	9	0	7	0	6	0	5	each.
Connecting pieces, or long screws	3	6	2	3	2	0	1	6	1	2	0	11	0	9	0	8	0	7	„
Bends, elbows, and springs, wrought iron	3	9	2	3	1	9	1	0	0	10	0	8	0	7	0	6½	0	6½	„
Crosses ditto	4	9	3	3	3	0	2	3	1	9	1	6	1	3	1	0	1	0	„
Tees ditto	3	9	2	6	2	0	1	6	1	1	0	9	0	7	0	6½	0	6½	„
Cocks (iron), full size, round way........	18	0	11	0	8	6	5	0	3	9	3	0	2	6	2	6	2	6	„
Caps, plugs, nipples, back nuts, and diminishing sockets	1	3	0	9	0	8	0	6	0	5	0	4½	0	4½	0	4	0	4	„
Sockets	1	0	0	8	0	7	0	5	0	4	0	3	0	3	0	2½	0	2½	„
Flanges	2	0	1	9	1	6	1	4	1	2	1	0	0	10	0	10	0	10	„
Elbows and bends (cast)	3	6	2	0	1	6	0	11	0	9	0	7							
Tongs or nippers, for pipe	4	8	4	0	3	2	2	9	2	3	2	0	1	8	1	8	1	8	per pair.
Ditto for socket..	6	0	4	8	4	0	3	2	2	9	2	3	2	0	2	0	2	0	„

Discount, ...

STOCKS AND DIES.

A SET.			B SET.			C SET.			D SET.		
⅛.	¼.	⅜.	½.	¾	1.	1¼.	1½.	2.	2¼.	2½.	3.
£2 0 0			£3 10 0			£6 10 0			£14 0 0		

For copper threads, with taps, ⅜-in., ½-in., and ⅝-in.	£1	10	0	per set.
Ditto without ⅜-in., ½-in., and ⅝-in.	0	18	0	„

STEAM COCKS AND GAUGES.

Improved ¼-in. gun-metal steam cocks	0	3	0	each.
Ditto ⅜-in. ditto	0	4	0	„
Ditto ½-in. ditto	0	5	6	„
Ditto ¾-in. ditto	0	9	9	„
Ditto 1-in. ditto	0	13	0	„
Ditto 1¼-in. ditto	0	17	6	„
Ditto 1½-in. ditto	1	0	0	„
Water-Gauges, with ⅝-in. glass tube, complete	1	16	0	„
Tallow Cups..	0	7	6	„

Bound by
LEWIS & SONS
GOUGH SQUARE
FLEET S^T LONDON